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THE DISTRIBUTION OF ANIMALS AFTER THE DELUGE[1]

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HAVING considered the first creation of the animal kingdom, and the larger features of its history to the time of the Deluge, bringing us to that era when our globe had assumed its present general characters, and its population was in those circumstances that led to their present habits and stations: the next subject to be discussed is their geographical and local distribution.

What had taken place in this respect before the Deluge we have no means of ascertaining. That the original temperature of the earth was once more equal than it is now, seems to be the general opinion of men of science, however they may differ as to its cause. If this was the case, as it probably was, any individual species might have been located in any country, north or south, and suffer no inconvenience from unaccustomed heat or cold, so as to interfere with its complete naturalization: the only other requisite would be a kind of food suited to its nature; and it is singular and worthy of particular attention, that a large proportion of the plants, as well as animals, that are found in a fossil state in our northern latitudes are of a tropical type or character.

After their creation, and perhaps the expulsion of the first pair from Paradise, we may suppose that the various animals of the ante-diluvian world were guided to those regions in which it was the will of Providence to place them, by a divine impulse upon them, which caused them to move in the right direction. Probably before the Deluge took place, the world was everywhere peopled with

[1] First part of Chapter II of "The History, Habits and Instincts of Animals," being part of the Bridgewater Treatises, established by the will of the Earl of Bridgewater with a bequest of eight thousand pounds placed at the disposal of the president of the Royal Society for works "On the Power, Wisdom and Goodness of God, as manifested in the Creation." Published by Carey, Lea and Blanchard, Philadelphia, 1836.

animals: and perhaps, as Professor Buckland has suggested, the sudden change of temperature that destroyed the northern animals might be one of the predisposing causes of that event.

Under the present head, the geographical distribution of our post-diluvian races of animals, the first thing to be considered is the means by which, after quitting the ark, they were conveyed to the other parts of the globe. The disembarkation of the venerable patriarch and his family, followed by all the animals preserved with him in the ark, a scene of universal jubilee to man and beast, such as the world till that day had never witnessed, took place on Mount Ararat: the stream of interpreters, ancient and modern, place this mountain in Armenia; but Shuckford, after Sir Walter Raleigh, seems to think that Ararat was further to the east, and belonged to the great range anciently called Caucasus and Imaus, which terminates in the Himmaleh mountains to the north of India. This opinion seems to receive some confirmation from Scripture, for it is said, *"As they journeyed from the east, they found a plain in the land of Shinar."* Now the Armenian Ararat is to the *north* of Babylonia, whereas the Indian is to the *east*. Again, as the ark rested upon Ararat more than *ten* weeks before the tops of the mountains were seen, it seems to follow that it must have been a much higher mountain than the generality of those of the old world. The modern Ararat (Agri-Dagh) is not *three* miles above the level of the sea, whereas the highest peak of the Himmaleh range, Dhawalagiri, is *five*, and the highest mountain in the known world; so that the tops of a great number of mountains would have appeared previously had the ark rested upon the former Ararat, but not so if upon the latter. The traditions also of various nations, given by Shuckford, add strength to this opinion. In addition to these, the following lines, quoted in a late article on Sanscrit poetry, in the Quarterly Review, show what was the creed in India on this subject:

In the whole world of creation——
None were seen but these seven sages, Menu and the fish;
Years on years, and still unwearied, drew that fish the bark along,
Till at length it came where reared Himavan—its loftiest peak;
There at length they came, and, smiling, thus the fish addressed the sage:—
Bind thou now thy stately vessel to the peak of Himavan—
At the fishes' mandate, quickly to the peak of Himavan:
Bound the sage his bark, and even to this day that loftiest peak
Bears the name of Naubandhana.

Both these opinions have their difficulties, which I shall not further discuss, but leave the decision of the question to persons better qualified than myself to direct the public judgment: I shall only observe, that perhaps the Indian station was more central and convenient for the ready dispersion of men and animals than the Armenian

one. Every naturalist is aware that there are many animals that, in a wild state, are to be found only in particular countries and climates. Thus the Monkey and Parrot tribes usually inhabit a warm climate, the Bears and Gulls with many other Sea-birds, for the most part a cold one. The Kangaroo and Emu are only found in New Holland; the Lama in Peru; the Hippopotamus and Ostrich in Africa. Now we may ask, how were all these local animals conveyed from the place of disembarkation to the countries and climates that they severally inhabit? In considering this question, we must never lose sight of Him, according to whose will, and by whose Almighty guidance, they were all led to the stations he had appointed for them, and with reference to which he had organized and formed them. Whatever second causes he might commission to effect this purpose, they were fully instructed and empowered by him to accomplish the work intrusted to them. I do not mean here to infringe the rule, *Nec Deus intersit nisi dignus vindice nodus.* Where the faculties, senses, and wants of an animal were sufficient for its guidance, there was no need for Divine interposition, but where these are insufficient guides, the animal must attain its destined station under some other influence.

What brought the various animals to the ark previously to the deluge? Doubtless a *divine* impulse upon them, similar to that which caused the milch-kine to carry the ark of the covenant to Bethshemesh, with the offerings of the lords of the Philistines. Noah, though he probably selected the clean animals, at least those that were domesticated, could have little or no influence over the wild ones to compel them to congregate by pairs, at the time fixed upon for their entry into the ark. So in the dispersion of animals, wherever man went he took his flocks and herds, and domestic poultry, and those in his employment for other purposes, with him: but the wild ones were left to follow as they would, or rather as God directed.

Every one who looks at a map of the world, on Mercator's projection, can easily conceive how the animal population of the greatest part of the old world made their way into the different countries of which it consists, but when he looks at America and New Holland, he feels himself unable satisfactorily to explain the migration of animals thither, especially those that can live only in a warm climate, at least as far as regards the former. How, he might ask, did the Sloths, the Anteaters, and the Armadillos get to South America? If the climate of Behrings Straits, after the deluge, was as cold as it is at this day, they could never have made their way thither, and in those latitudes the temperature of which was adapted to their organization the vast Pacific presents an insuperable barrier.

The same question may be asked with respect to the indigenous animals of New Holland; the Kangaroo, the Cola, the Ornithorhynchus, the Emu, and several others that are found in no other country; how did they, leaving the continent altogether, convey themselves to this their appointed abode? It is true difficulty is not so great in this last case, on account of the numerous islands interposed between Malacca, Cochin-China, etc., and the North Coast of New Holland, but then it is unaccountable, if the transit of these animals was gradually effected by natural causes, and following that of mankind from island to island, till they reached the country to which their range is now limited, that they should have left no remains of their race in the countries and islands which they must have traversed in their route; and those that would have accompanied man would be a different tribe of animals, more fitted to minister to his wants, so that with respect to these the difficulty still remains—they could not have reached the country unless under the guidance of Providence, and the same power that accomplished their removal to that appointed for their residence, prevented their leaving any of their race in the regions through which they passed.

There is only one supposition that will enable us to account for the transport of these animals in a natural way, which is this, that immediately subsequent to the deluge, America and New Holland, and the various other islands that are inhabited by peculiar animals, were once connected with Asia and Africa, by the intervention of lands that have since been submerged. Plato, in his Timæus, relates a tradition concerning an island called Atlantis, which he describes as bigger than Asia and Africa, situated before the pillars of Hercules, which after an earthquake was swallowed up by the sea. According to his statement, this account was given by the Egyptian priests at Sais, to Solon, the Athenian legislator. Catcott, in his history of the deluge, seems to give some credit to this tradition, and supposes that Phaleg took his name, not from the confusion of tongues at Babel, and the subsequent division of the earth amongst the families of the three sons of Noah, but from its division occasioned by the subsidence of this great island, by which the occidental were separated from the oriental countries of the globe. Philo Judæus speaks of this catastrophe in terms that imply he gave credit to it, as does also Tertullian; but it appears to me to rest on too uncertain a base, and to be too much mixed with evident fable and allegory, to claim full credit as a real fact in the history of our globe. Still that many violent convulsions have taken place since the deluge is generally supposed. Our own island is thought once to have formed part of the continent, Sicily to have been united to Italy, with many other instances mentioned

by Pliny. It is equally probable that the islands of the Indian Archipelago were at one time joined to that part of Asia. Whether such disruptions from the continents were simultaneous, or took place at different periods, is uncertain; but if such an event as the submersion of the vast island of Plato did really happen, it surely would affect the whole terraqueous globe, produce convulsions far and wide, and cause various disruptions in its crust, and elevations in other parts from the bed of the ocean. It throws some weight into this scale, that thus a way would be open, though certainly a circuitous one, for the migration of those animals to America, that are found in no other part of the world, and, supposing Asia to have been disrupted from it at Behrings Straits, could scarcely have ascended to so high a latitude, in search of their destined home.

Malte-Brun, in his geography, after proving that the animals in question could have passed neither from Africa nor Asia, observes—"Nothing, therefore, remains, but the accommodating resource of a tremendous convulsion of nature, with a vast tract of country swallowed up by the waves, which formerly united America with the temperate regions of the old world. Such conjectures as these, however, being devoid of all historical support, do not merit a moment's consideration; consequently we can not refrain from admitting, that the animals of America originated on the very soil, which, to this present day, they still inhabit."

That it might have been the will of the Creator to people the country in question by the immediate production of a new race of animals, suited to its climate and circumstances, I will not deny, but I would only ask, is it consistent with what occurred at the deluge? Surely the task of Noah would have been much less difficult and laborious, had it been merely necessary for him to construct a vessel fitted for the reception of himself and family, and of food for their sustenance during their confinement; and a new race of animals had been created, adapted to the then state of the earth and mankind. But such was not the will of God, and, doubtless, for wise reasons. He would neither create a new race of men, nor a new race of animals, when the world might be repeopled by those already in being. This would not have harmonized with the ordinary proceedings of his providence. Whoever examines the animals of North America, will find a vast number that correspond with European species, distinguished only by characters that mark varieties. On the Rocky Mountains, and in the country westward of that range, Asiatic types are discoverable, both in the vegetable and animal kingdoms. Several animals, likewise, of the southern part of that Continent belong to old world genera, and also species. I have received from Valparaiso a beetle, common in Britain, and Molina mentions several other European genera, as natives of

Chili; so part of the animal population of the New World appears to have been derived from Europe and Asia; and if so, there is a door open, through which Providence might also have conducted those North American animals that are found in no other country.

But besides the probable, or possible, modes by which the transit of animals to their respective settlements might have been accomplished, Mr. Lyell, in the second volume of his Principles of Geology, has suggested one which might, amongst others, have been employed for this purpose.

"Captain W. H. Smyth informs me," says he, "that, when cruising in the Cornwallis, amidst the Philippine Islands, he has more than once seen, after those dreadful hurricanes called typhoons, floating islands of (*matted*) wood, with trees growing upon them; and that ships have sometimes been in imminent peril, in consequence of mistaking them for terra firma." Mr. Lyell conjectures, not improbably, that by means of such an insular raft, or wandering Delos,—"if the surface of the deep be calm, and the rafts carried along by a current, or wafted by a slight breath of air fanning the foliage of the green trees, it may arrive, after a passage of several weeks, at the bay of an island, into which its plants and animals may be poured out as from an ark; and thus a colony of several hundred new species may at once be naturalized." Thus he accounts for the peopling of the volcanic and coral islands in the Pacific.

It must be borne in mind that nothing really happens by chance, or is the result of an accidental concourse of fortuitous events: second causes are always under the direction of the *first*, who ordereth all things according to the good pleasure of his will; and therefore the elevation of a new island from the bosom of the deep, whether immediately produced by volcanic agency, or by an earthquake, or built by Zoophytes, still may be denominated *his* work; so likewise the same Almighty Guardian of the universe, whose name is Jehovah of Hosts, directs all the actions and motions of the hosts that he hath created, to the full accomplishment of every purpose that, in his wisdom, he hath formed. When we are assured that the hairs of our head are all numbered, and that not a sparrow falleth without our Heavenly Father, we are instructed to look beyond second causes for the direction and management of events that appear at first sight the most trivial, but which, in their immediate or remote consequences, may be productive of effects that are important to be attended to and provided for.

We know that when animals of any kind exceed certain limits, though beneficial in the ordinary exercise of their instincts, they become noxious. God alone knows when they approach these limits; it is he, therefore, that employs man or other animals to destroy a certain number of them, that they may bear a due proportion to

other beings on which they act; or if he wills to punish mankind, he suffers their numbers to increase so as to answer this intention. But to all his hosts, he says, "*Thus far shalt thou go and no further.*" Therefore, when the ocean, or fires below its bed, or other causes elevate islands above its surface, it is he that conducts to them the population he intends should occupy them.

The islands of Bourbon and Mauritius both appear to be of volcanic origin: amongst their aboriginal animal inhabitants was a most extraordinary gallinaceous bird, called the Dodo; this bird, like the ostrich and cassowary, had only rudiments of wings, and of course was unable to fly; being unfit for food, though of the gallinaceous order, and a very ugly and disgusting object, it soon became extinct in those islands, and the only remains of it are a leg and foot at the British Museum, and a skeleton of the head in the Ashmolean Museum at Oxford. It has been contended that this bird, having never been discovered elsewhere, was peculiar to these islands, but there are reasons for believing that it was not the only species of its genus, for Latham has included in it two others, both stated to have been found in African islands. This affords a strong presumption that the headquarters of the genus are on the continent of Africa, and that these three species have been conveyed to the islands they are stated to have inhabited by some accidental cause. By the direction of Providence, a floating island, like that seen by Captain Smyth, might be the means of conveying this and their other inhabitants to them.

I think, therefore, that there is no necessity to have recourse to a new and more recent creation, to account for the introduction of its peculiar animals into any given country.

The fact itself, that almost every country has its peculiar animals, affords a proof of design, and of the adaptation of means to an end, demonstrating the intervention and guidance of an invisible Being, of irresistible power, to whose will all things yield obedience, and whose wisdom and goodness are conspicuous in all the arrangements he has made. Wherever we see a peculiar class of animals we usually see peculiar circumstances which require their presence. Thus the elephant and rhinoceros, the lion and the tiger, are found only in warm climates, where a rapid vegetation, and infinite hosts of animals, seem to require the efforts of such gigantic and ferocious devourers to keep them in check: but on this subject I shall have occasion to enlarge hereafter.

There is another point of view, illustrative of the Divine attributes in this partial location of various animals. If every region, or nation, contained within its limits the entire circle that constitutes the animal kingdom, and the remark may be extended to every natural object, how weak and trifling would be the incitement for

man to visit his fellowman. Were the productions of every country the same, there would be little or no temptation for commercial speculation, therefore the merchant would stay at home; the animal, and plants, and minerals would be the same, therefore the naturalist would stay at home; the astronomer indeed, and geographer, and the student of his own species, might be tempted sometimes to roam, but the ocean would be truly *dissociable*, and those ties that now connect the different nations of the globe would, for the most part, be broken. They are now linked to each other, in a bond of amity, by the intercourse which their mutual wants produce, and the body geographical, if I may use such a metaphor, as well as the body natural, is so tempered, and so furnished in every part, that constant supplies of things, necessary or desirable, are uninterruptedly circulating, by certain channels, through the whole system; and thus keep up a kind of systole and diastole, which diffuses everywhere a healthy temperament, and is universally beneficial. It is, moreover, calculated to generate those kindly feelings which ought to reciprocate between beings inhabiting the same globe, and sprung from the same original father. And the cultivation of these feelings of mutual good will was, no doubt, the principal object of the Deity in the distribution of various gifts to various countries, endowing some with one peculiar production and some with another: so that one might not say to another, "*I have no need of you.*"

Herein is the Divine wisdom and goodness most conspicuous. Had chance, or nature, as some love to speak, directed the distribution of animals, and they were abandoned to themselves and to the circumstances in which they found themselves in their original station, without any superintending power to guide them, they would not so invariably have fixed themselves in the climates and regions for which they were evidently intended. Their migrations, under their own sole guidance, would have depended, for their direction, upon the season of the year, at which the desire seized them to change their quarters: in the height of summer, the tropical animals might have taken a direction further removed from the tropics; and, in winter, those of colder climates might have journeyed towards instead of from them. Besides, taking into consideration other motives, from casual circumstances, that might have induced different individuals belonging to the same climates to pursue different routes, they might be misled by cupidity, or dislike, or fear. On no other principle, can we explain the adaptation of their organization to the state and productions of the country in which we find them—I speak of local species—but that of a Supreme Power, who formed and furnished the country, organized them for it, and guided them into it.

THE STATE OF SCIENCE IN 1924[1]

THE ORIGIN OF MAN

By ARTHUR SMITH WOODWARD, LL.D., F.R.S.

Relationship between Man and the Apes

There are many structures in the human body not specially adapted for present use, which can only be satisfactorily explained by supposing that man is descended from animals which once lived in trees. The structures are so numerous and so striking that a few years ago Professor F. Wood Jones wrote a whole book about them entitled "Arboreal Man." It has indeed been said that if there had been no trees in the world, there could never have been man in his present form.

If this inference be correct, we naturally look to the apes and monkeys of the present day as affording the best idea of the ancestors which we suppose to have existed. We thus, on strictly scientific grounds, recognize a relationship between man and apes, which has long been fancifully imagined by speculators who have merely been familiar with their external appearance. Science, however, would not admit that any of the existing apes are the unaltered descendants of those which, ages ago, gave rise to man. Just as man has gradually become a perfect biped, adapted for an easy upright gait when walking on the ground, so the apes have acquired an increasingly effective adaptation for swinging about in trees. Just as man has lost the power of his jaws in proportion as his hands have become more mobile, so the apes have acquired more powerful jaws and teeth both to increase the efficiency of their feeding and to improve their means of offense and defense. Science, indeed, points to a remote common ancestor of man and apes, which might by changes in two divergent directions become either one or the other. This ancestor, of course, would be popularly described as an ape if it happened to be still living, but it would be very different from any modern ape. It would be less forbidding in aspect—more like the comparatively fascinating baby of the modern ape.

Unfortunately, of animals which formerly lived in the world, we scarcely ever find more than the hard parts. Of ancestral apes and man we can only expect to discover the bones and teeth. The nature of the soft parts, therefore, can only be inferred from the shape and

[1] Prepared for the Handbook to the Exhibit of Pure Science, arranged by the Royal Society for the British Empire Exhibition.

markings of the bones. In fact, in searching for ancestors the skeleton alone concerns us.

Points of Contrast

The skeleton in both apes and man happens to be very characteristic and it is easy to distinguish the former from the latter. First, in all the apes the brain-case is comparatively small, and the face very large, often prominent; in modern man the brain-case is large and beautifully domed, while the face is comparatively small. Secondly, most of the apes have relatively large and prominent bony brow-ridges when they are full-grown; modern man lacks such brow-ridges. Thirdly, in all the apes the bony chin is receding, and the canine (or corner) teeth are relatively large and interlocking, as in a dog or cat; in modern man the bony chin is a little prominent at its lower edge, and the canine teeth are neither large nor interlocking—they are in an even series with the rest of the teeth. Fourthly, in all the apes the backbone is nearly straight—it is so even in the gibbons, which can run swiftly on their hind limbs; in modern man the backbone has a beautiful S-shaped curvature to produce the elasticity which is needed for a comfortable upright gait. Fifthly, in all existing apes, at least, the arms are relatively much longer than in man, and the great toe is as well adapted for grasping as the thumb. Sixthly, in the apes, as a rule, the thigh-bone is somewhat arched, and the shin-bone comparatively short and stout, in adaptation to the crouching gait; in upstanding modern man the thigh-bone is nearly straight.

If the theory of man's origin in an ape-like ancestor is well founded, the older the human skeletons that we find buried in the earth, the more closely they should approach ape-skeletons in the distinctive features just enumerated. Among the fossils there should indeed be "missing links." The study of other fossil animals leads us to suppose that we shall not find a single graduated series of missing links, but a multitude of forms of approach of the human frame to the ape-condition. We must infer, in short, that existing modern man is the triumphant survivor of many tentative advances towards a being with an overgrown and elaborate brain which should dominate and increasingly control the rest of nature.

Early Man in Java

The great difficulty is that very few remains of man's ancestors have been discovered which date back before the time when he had so far progressed as to acquire ideas of a future life and hence to bury his dead in security. Before that time, human remains could be preserved only when an individual happened to fall into a hole or into a river or lake where the body could be covered up with sand or

gravel or mud. Hitherto, the remains of not more than three such accidents have been discovered, and even in these cases only fragments of the skeletons have been preserved, so that we have very little material for the investigation of the subject.

The first of the discoveries of early man just mentioned was made by Professor Eugene Dubois in 1892, in an old river deposit in Java, which also contained the remains of extinct kinds of elephant and rhinoceros and other animals closely related to those still living in the East Indies. The principal fragment recovered is the top of a skull as large as that of a small man, with immense ape-like bony brow-ridges instead of the usual human forehead, but with impressions of a brain which is said to have been essentially human. Two associated teeth are not completely human, but in some ways resemble those of the little gibbon which still lives in the forests of Java. A thigh-bone, which is rather disappointing as being affected by disease at the upper end, is as straight as that of a man or a gibbon, and implies the possibility of an upright gait. If all these remains belong to one individual, as seems most probable, they represent either an ancestral man who approached the apes in his brow-ridges and teeth, or a gigantic gibbon which had an unusually enlarged brain. In any case, the being was well named *Pithecanthropus*—the ape man—by Professor Dubois, who was justified in claiming it as one of the "missing links." The specimens are now in the Teyler Museum at Haarlem, in Holland.

Heidelberg Man

The second discovery, which seems to date back to the time before man buried his dead, was made in a thick bed of sand deposited by a river at Mauer, near Heidelberg, in Germany, and was described by the late Professor Otto Schoetensack in 1907. It consists solely of a lower jaw, which was found in association with the bones and teeth of elephant, rhinoceros, hippopotamus and other animals which are known to have lived in Europe at the beginning of the Pleistocene period of geologists. The jaw is astonishingly large and massive, and, though essentially human, it differs from every known human jaw in the backward slope of the bony chin, which in this respect approaches that of the ape. At the same time, it contains typically human teeth in even series, without any enlargement or prominence of the canines. The fossil thus seems to represent an extinct species of man, *Homo heidelbergensis*, who still retained the retreating bony chin. It is now in the Geological Museum of the University of Heidelberg.

Piltdown Man.

The third very early accident to a primitive human being was revealed in an old river-gravel at Piltdown, Sussex, by the late Mr.

Charles Dawson in 1912. This gravel occurs in the Wealden country about midway between the southern chalk down and the sandstone ridge on which Crowborough is situated. It contains many water-worn flints which were derived from the chalk, and as no river in that part of Sussex could now bring them to the Piltdown district, it evidently dates back to a time when the local topography was entirely different from that of the present. It also contains fragments of elephant, hippopotamus and other animals, which show that it dates back at least to the beginning of the Pleistocene period.

The only fragments of a human skeleton hitherto discovered are the greater part of a skull and nearly half of a lower jaw with two molars and a canine tooth. The skull agrees with that in some existing low races of men in being remarkably thick, but it is unique in having a very fine spongy texture, which would make it highly resistant to blows. It is as destitute of bony brow-ridges as the skull of modern man, with a good forehead, but the crown of the head is less domed than usual, and the hinder or occipital part remarkably low and broad. The brain must have been essentially human, and it is distinctly larger than the smallest human brain of the present day; but it exhibits some peculiarities that are more suggestive of the ape pattern than any other human brain hitherto studied. The whole skull, indeed, is curious, and must have belonged to a human creature very different from modern man. The lower jaw is comparatively weak, but it is so much elongated that it implies a relatively large face. Its retreating bony chin is shaped almost exactly like that of an ape; it is much more ape-like than that of *Homo heidelbergensis*. The molar teeth, though essentially human, are unusually large and elongated; and the much-enlarged canine tooth is so worn as to show that it completely interlocked with the upper canine, as in an ape. This canine tooth, however, differs in shape from that of any known ape, and agrees best with the temporary (or milk) canine of modern man. It is certainly a tooth of the permanent series, and therefore represents the first or preliminary stage in the making of a typical human dentition.

Piltdown man indeed belongs to the real dawn of the human race, and has been appropriately named *Eoanthropus*, or dawn man. The original specimens, with fragments of a second skull and molar tooth discovered by Mr. Dawson in another locality near Piltdown, are now in the Geological Department of the British Museum (Natural History).

Neanderthal Man

The earliest form of man in Europe who was intentionally buried in security after death is now known by several more or less nearly complete skeletons from the caves and rock shelters of France and

Belgium. The first skeleton, of which only the top of the skull and a few other fragments were rescued from destruction, was found in the Neanderthal (or valley of the Neander) near Düsseldorf in Germany. The best French skeletons were found with flint implements of the peculiar pattern which is met with in the cave of Le Moustier in the Dordogne. The race represented is therefore commonly known as that of Neanderthal or Mousterian man.

The finest skeleton of Neanderthal man, which was described by Professor Marcellin Boule and is now in the National Museum of Natural History at Paris, was found in 1908 in a small cave near La Chapelle-aux-Saints in the Corrèze in S. W. France. The circumstances showed that it had been intentionally buried, while the associated flint implements and remains of woolly rhinoceros, reindeer, hyena and other animals proved its geological age. A leg of a bison, which must have been covered with flesh when it was buried, seems to have been placed there as food for the deceased in a future life. The skull is relatively the largest ever seen in healthy man, and the brain-case, which is curiously depressed and expanded behind, is larger than that of the average modern European. The brain, however, may have been inferior in quality. There are strongly inflated bony brow-ridges, as in an ape; and the face also slightly approaches that of an ape in being relatively large and in having no depression in the bony cheek beneath the eye. The mouth is also very large, but the teeth are in all respects typically human, and the bony chin only differs from that of modern man in being sharply truncated, not prominent near the lower edge. The backbone is remarkably stout, about two inches shorter than usual, and the man must have been of short stature. The arm is relatively long, and the two bones of the forearm are much arched, thus again retaining marked traces of an ape ancestry. The thigh bone is stouter and more bent than in ordinary man, and the shin bone is comparatively short and stout. While essentially human, therefore, Neanderthal man had probably a slouching rather than an upright gait, and his heavy face would give him a bestial aspect.

The Home of Modern Man

We may, then, pause to remark that the earliest known fossil remains of man approach the hypothetical ape ancestor in at least two distinct ways. In one case there are no bony brow-ridges, but an ape-like jaw; in the other case, there are great bony brow-ridges, but a typically human jaw. So far as the scanty evidence goes, it fulfils our expectation of finding more than one kind of "missing link."

In western Europe there is still no indication of typically modern man having lived with the immature grades of humanity just

described. All statements to the contrary are based on modern burials which have been wrongly interpreted. In the metropolis of early man in central France, however, typically human skeletons are found in deposits in the rock shelters and caves which are immediately above those containing the remains or handiwork of Neanderthal man. As no skeletons of an intermediate race have been discovered, it may therefore be inferred that modern man originated elsewhere and appeared as an immigrant in this part of the world. Indeed, all our present knowledge suggests that the successive phases of dawning humanity were passed through somewhere in the east, probably in south central Asia. In that case, the periodical westward migration of peoples which is so familiar a feature of historic times must have begun in remote prehistoric antiquity.

One reason for suspecting that south central Asia may have been the original home of man is that just before his beginning a very varied assemblage of great apes lived in the forests of northern India. They are unfortunately known only from a few scattered teeth and fragments of jaws found in the deposits of Miocene age which now form the Siwalik Hills, so that we have very little information about them; but no such series of great apes has hitherto been discovered elsewhere. Now, at the beginning of the Miocene period, the Himalayan Mountains did not exist, and (as the late Joseph Barrell first suggested) it may have been during the uplift of this mountain range at the end of the period that primitive man came into being. As the land rose, the temperature would be lowered, and some of the apes which had previously lived in the warm forest would be trapped to the north of the raised area. As comparatively dry plains would there take the place of forests, and as the apes could no longer migrate southwards, those that survived must have become adapted for living on the ground, and acquired carnivorous instead of frugivorous habits. By continued development of the brain and increase in bodily size, such ground apes would tend to become man.

The Natives of Australia and Tasmania

It has long been generally recognized that the lowest races of men in the present-day world are the blacks who inhabit Australia and those who until lately survived in Tasmania. They have often been regarded as closely related to the Neanderthal man who disappeared so long ago from Europe; but the discoveries of skeletons in France, already mentioned, show that the two races are entirely different. The remote lands of the southern hemisphere have always been the refuges in which old types of life have survived long after they became out of date and displaced in the more

progressive northern hemisphere. There is, however, still no evidence of the Neanderthal or any earlier race in the south, and the Australians and Tasmanians are probably the survivors of the true men of later Pleistocene times. Their immediate ancestors seem to have had a much wider range in the southern hemisphere at a recent period, for an Australoid skull is known from a rock shelter at Wadjate in Java, and another skull, associated with parts of the skeleton, which seems to have similar relationships, was found in 1921 buried in a cave in Northern Rhodesia. The Rhodesian skull, however, is unique in having the most inflated bony brow-ridges and the largest face ever seen in man. At first sight, these features seem more ape-like even than the corresponding parts of the European Neanderthal man; but more careful examination shows that the face is not enlarged on the ape model—the enlargement is not in the middle of the face, as in the ape, but round the edge—and the only known specimen which approaches the Rhodesian in the depth and extent of the bone below the nostril is a fossil Australian skull from Talgai in Queensland. In the characters of his brows and face, therefore, Rhodesian man probably exhibits merely a modern reversion to an ancient human type.

It may be added that man does not appear to have reached the American continent until much more recent times, for none of the fossil remains hitherto found in that region of the world differs essentially from the corresponding parts of the skeleton of the existing American Indians.

INSECT MIMICRY AND THE DARWINIAN THEORY OF NATURAL SELECTION

By Professor E. B. POULTON, F.R.S.

THE superficial resemblances between insects constantly attracted the attention of the older naturalists, as we realize from the names they gave when they called certain moths "bee-like," "wasp-like," etc. It was the same with resemblance to surroundings. The fine old naturalist, W. J. Burchell, writing more than a hundred years ago of his travels in the interior of South Africa, described a grasshopper which exactly resembled a stone and also fleshy plants of the Karoo which were hidden in the same way. He fully recognized the benefit conferred by this likeness, but held the common belief of his day that insect and plant came into existence exactly as we see them and that their resemblances were part of "the harmony with which they have been adapted by the Creator to each other and to the situations in which they are found."

The appearance of Darwin's "Origin of Species" in 1859 brought clear evidence that animals and plants had reached their present state by a process of evolution, and that the main motive cause had been natural selection or the survival of the fittest, acting upon hereditary variations. One of the first problems to which these principles came to be applied was insect mimicry and the protective resemblances or concealing colors and shapes of insects—both resemblances so widespread and evident in nature that the failure to explain them on Darwinian principles would have meant the breakdown of the principles themselves. Insect mimicry and insect concealment became test problems. If produced by natural selection these resemblances must be beneficial and must have been attained by transition from different and less beneficial stages.

It is necessary at the outset to clear away certain misconceptions which here arise from the word 'mimicry," used in ordinary speech to signify conscious imitation. As used technically for these deceptive superficial resemblances, conscious imitation is out of the question. No insect "by taking thought" can effect any change in its own appearance. Mimicry is akin to protective resemblance and is sometimes employed to include the latter; but it is convenient to keep the two separate because they lead to such different kinds of appearance. In mimicry, an insect resembles another, the model, which possesses some special defense, such as a sting, an unpleasant taste or smell, etc., and advertises its powers by conspicuous warning colors. The mimic therefore becomes itself conspicuous. In protective resemblance, on the contrary, an insect resembles something, such as earth or bark, of no interest to its enemies, and in resembling it becomes concealed.

Early Recognition of Mimicry

Returning to the relation between mimicry and natural selection, it must have been obvious to naturalists for many years that the resemblance of a stingless moth or fly to a bee or wasp is likely to be advantageous. It was otherwise with the likeness between many butterflies and day-flying moths collected by H. W. Bates in the Amazon Valley—striking likenesses of color and pattern in each locality, all changing together, "as it were with the touch of an enchanter's wand," in passing from one area to another. The late Dr. F. D. Godman has told us that Bates did not solve this problem in the tropics. The solution came after studying his collection at home and reflecting on his memories of the living insects. In November, 1861, just two years after the publication of the "Origin of Species," he read before the Linnean Society his classical paper in which it was shown that the imitated butterflies or "models" were specially abundant, conspicuous and slow-flying, and belonged

to groups with these characteristics, while the "mimics"—members of several widely separated groups—had departed from the colors and patterns still borne by their non-mimetic allies.

A few years later, in 1866, A. R. Wallace showed that Bates's interpretation was valid for the tropical east; and, again in a few years, Roland Trimen proved that it held in Africa. All three memoirs were published in the "Transactions" of the Linnean Society, and the last mentioned, appearing in 1870, showed for the first time that three swallowtail butterflies with entirely different patterns, and without "tails" to the hind wings, were the females of a fourth swallowtail which bore "tails" and was of a still more divergent pattern. All four had been described as different species. Trimen further showed that in Madagascar a closely allied male had a tailed female very like itself, and that on the mainland of Africa the "tails" had been lost and different patterns gained by the females in mimicry of three different species of the tailless group Danainæ which provides the chief models for mimicry in the east, and is closely allied to the chief models of tropical America.

Trimen's conclusions were received with incredulity, and indeed contempt by some of the older naturalists; but he lived to see them everywhere accepted, and put beyond the possibility of doubt by breeding the males and all three female forms in one family produced by a known female parent.

Types of Mimicry

Bates, in the great paper already referred to, directed attention to the fact that butterflies belonging to the groups which supply the models also mimic each other, and this puzzled him. The interpretation came in 1878, when Fritz Müller, a German naturalist living in Brazil and deeply influenced by the "Origin of Species" and by correspondence with Darwin, brought forward the theory which has since been known as Müllerian mimicry. He then showed the advantage of a resemblance between unpalatable conspicuous insects, because it reduces the number of warning patterns which must be learned by enemies and the number of injuries inflicted in learning them.

Batesian mimicry is like the action of a struggling unscrupulous firm which imitates the trade-mark or advertisement of a successful house. Müllerian mimicry is like the action of a group of powerful firms which become still better known at a lessened cost by combined advertisement.

The decision, whether any mimic is Batesian or Müllerian, is in some instances easy, in others difficult, and opinions are divided as to the relative importance of the two theories. When the allies of a mimetic species are well concealed by protective resemblances, then

the mimic is most probably Batesian; when the allies are specially protected and warningly colored, then the mimic is probably Müllerian, and has merely exchanged one warning pattern for another. Again, a large proportion of mimetic species are, like *Papilio dardanus*, only mimetic in the female sex, the original pattern of the female being retained by the male. Here the appearance of the male, and especially of its under-surface pattern, helps us to decide whether the female is a Batesian or a Müllerian mimic.

The prevalence of mimicry in the female was explained by A. R. Wallace by the greater needs of that sex—their greater weight and slower flight, and the necessity for them to alight and lay their eggs. Another cooperating explanation was suggested much later, namely, that the females are more variable than the males, and thus produce the requisite changes of pattern more freely.

Origin of Mimicry

There can be little doubt that Mendelian heredity has been of great importance in the origin of mimicry, diminishing the "swamping effect of inter-crossing" between the parent form and the incipient mimic and between the different fully formed mimics belonging to one species, as in *P. dardanus*. There is also a considerable body of facts which suggest that Mendelian heredity does actually operate in this and other mimetic species, the most complete evidence being that obtained by Mr. J. C. F. Fryer by his breeding experiments on *Papilio polytes*. This species in Ceylon, where the experiments were conducted, has three forms of female, one like the male and two resembling other swallowtails which belong to a distasteful group. The Mendelian relationship was found to exist between these three females.

It is in the facts of geographical distribution that we find the most conclusive evidence of the production of mimicry by natural selection. Two Danaine butterflies in America belong to an Old World group, and are evidently recent invaders by way of the north. In temperate North America they have met the natives of the Northern Belt, among them the white admirals, allied to our own well-known species *sybilla*. If, therefore, mimetic resemblance is, as some have supposed, the common result of common causes associated with locality, the invader ought to have come to resemble the ancient resident, but as a matter of fact the resident has lost its original pattern and mimics the invader. The change, although immense, so far as the pattern is concerned, is so superficial and recent that the early stages are entirely unaffected, and the mimic can interbreed with another unchanged North American white admiral, producing an intermediate hybrid—an experiment successfully carried out by Mr. W. L. W. Field.

The Pseudacræas of tropical Africa, nearly all of them mimetic in both sexes, are butterflies closely allied to the white admirals. A species in Uganda, *eurytus,* is a very complicated example of mimicry, for this single species includes in the same locality three different forms, two with sexes alike mimicking two Acraeine species with sexes alike, one with sexes different mimicking the corresponding sexes of another Acraeine. The fact that all these mimics are one species was proved by breeding by Dr. G. D. H. Carpenter. Now in Uganda intermediates between these three forms of *eurytus* are rare, whereas on some of the islands in Lake Victoria they are very common, and Dr. Carpenter, who proved this fact, found that on these same islands the models are, for some unknown reason, rarer than their mimics. The facts suggest strongly that there is more severe extinction of intermediates in the presence of abundant models, but less severe when models are few.

Butterflies and day-flying moths are especially suitable for the study of mimicry, because the resemblances are chiefly shown in the colors and patterns on the broad surface of their wings, both colors and patterns being very variable, and thus affording material for rapid change by the operation of natural selection. But the same phenomena are conspicuous in other groups of insects, such as the beetles. We find among the beetles, as among the butterflies and moths, that the models belong to the distasteful warningly colored groups, and that members of these tend to mimic each other, as well as to be mimicked by species of less powerful groups.

The most convincing evidence of the production of mimetic likeness by the operation of natural selection is provided by a comparison of the different methods by which a resemblance to formidable insects, such as wasps and ants, has been attained. The variations which present the possible beginnings of such a likeness are determined by the present constitution of each species, and this again has been determined by its past history. Great difference in the method of resemblance is therefore to be expected and is found. In some flies the slender "waist" of a wasp is represented by an actual narrowing of the body; in certain beetles by a patch of white which "paints out" the superfluous thickness—a device very elaborately carried out in the young stages of an African long-horned grasshopper, which lives among green leaves and has the un-antlike parts of its body colored green—the antlike parts black.

Mimicry in Movement

The likeness requires astonishing readjustments when the mimicking animal is widely different from its model. Thus many small

spiders mimic ants; but spiders are not insects, having no antennæ, eight legs instead of six, and the body divided into two sections instead of three. A North American spider observed by Dr. and Mrs. Pecklam got over these difficulties by holding up one pair of legs to represent antennæ and by developing a groove across one of the body sections, making it look like two.

Mimetic likeness to be efficient nearly always demands appropriate movements, and these are often the most important part of the likeness, and sometimes the probable starting-point. Thus beetles which in the cabinet do not at all closely resemble a wasp may be convincingly wasplike in the rapidity and jerkiness of their movements. This is true of our British wasp-beetle and of a rather similar Brazilian species of which Burchell wrote on his later South American journey nearly one hundred years ago: "It runs rapidly like an ichneumon or wasp, of which it has the appearance." A note by the same naturalist on a small Brazilian spider suggests that the first stage of mimicry was produced in this way: "Black . . . runs and seems like an ant with large extended jaws." Now this spider does not belong to a group known to include antlike species, and Burchell's observation suggests, as Mr. R. I. Pocock has pointed out, "that the perfect imitation in shape, as well as in movement, seen in many species was started in forms of an appropriate size and color by the mimicry of movements alone."

Natural Selection and the Production of Mimicry and Protective Resemblance

Of all the methods by which mimicry and protective resemblance also is produced, the most remarkable and the most convincing as evidence for the operation of natural selection is that followed by tropical American insects allied to the Cicadas and our too well-known greenfly. It is only because these insects—the Membracidæ—are all of them small that the examples are unfamiliar and the lessons they teach unknown to many who are interested in the subject. The body of these little insects is shaped much like that of the greenfly, but it is completely hidden when looked at from above by a covering shield, which is developed from the body-ring behind the head and grows backwards. Therefore, when the insect is concealed by resembling some object such as a thorn or mimics an ant, the deceptive likeness to be of any use must appear in the covering shield, and not in the hidden body; and this is exactly what has happened.

The criticism has been urged by Jacobi that these insects, when disturbed, leap like their relatives, the froghoppers, and therefore

the mimicry of an ant is meaningless. This is a good example of the kind of objection often raised against the theory of mimicry. But, if a hopping insect comes to resemble an ant, it still stands to gain by keeping its older means of escape when the newer one is seen through by an enemy.

Another objection often brought forward, especially against the theory of mimicry as applied to butterflies, is the assertion that these insects are rarely attacked, if at all, by birds—the only enemies which are believed to cause first the growth and then the maintenance of a deceptive resemblance to the model, by destroying on the average more of the unlike and less of the like in each generation. The critics have especially relied upon the insufficiency of direct evidence of such attacks, and the almost complete absence of butterfly remains from the stomachs of an immense number of American birds which were examined in order to determine the nature of their food.

In reply to the former objection, Dr. G. A. K. Marshall collected and published in 1909 all the observations recorded up to that date, and proved that the evidence was much stronger than had been supposed. Furthermore, attention having been thus directed to the subject, many naturalists, especially Mr. C. F. M. Swynnerton, Dr. G. D. H. Carpenter and Captain W. A. Lamborn, made a special study of the relation between birds and butterflies in various parts of Africa, and soon produced abundant positive evidence. Mr. Swynnerton and Captain Lamborn also directed attention to the frequent presence of birds' beak-marks upon the wings of butterflies, marks which afford the strongest circumstantial evidence of attack. Beautiful examples of these impressions of beaks on Fijian butterflies have still more recently been received from Mr. H. W. Simmonds.

As regards the objection founded on American birds, Mr. Swynnerton has proved, and Captain Lamborn has confirmed, that the digestion of birds is remarkably rapid, and that a butterfly is quickly reduced to a condition in which it can only be recognized by means of the compound microscope.

The facts of mimicry and protective resemblances are now patent to all, and no valid interpretation of these facts except that which is based on the theory of natural selection has ever been offered.

AN EVOLUTIONARY DEMOCRAT[1]

By Professor FREDERICK H. BLODGETT
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POLITICAL parties and their leaders may be thought of as examples of organization or activity among which response to environment may be expected to be the least evident, since leadership by the few rather than mutual influence of the many is the common condition. But a little while with a good history will show that even the safe and sane organization so widely recognized as the Grand Old Party, or its active associate with the flying heels and wagging ears, have responded to the influence of their environment from time to time, and have modified their aims, methods and modes of action.

A former secretary of state has been very active for some months, now amounting to several years, in an active, but intermittent attack upon what he thinks is meant among biologists by evolution, disregarding the fact that he is himself an example and product of the very forces which he so verbosely decries. The doctrines of the political party whose banner he has so many times upheld have undergone a very definite evolution, and his own attitude toward the principles worthy of a nation's support in party platforms or governmental policies has also been changed in accordance with the changes taking place in social conditions during the thirty years since he first advocated "Free Silver" and "Free Trade" as panaceas for discontent. This accomplished speaker of the prairie lands would be most unwilling to be charged with having made no advance in political development in this period or of having remained blind and unresponsive to the influence of the changes taking place all about him, in business, industry, social and political activities, and in the general increase in range of knowledge as represented by average high-school graduates of his home town.

Evolution has had its influence upon Mr. William Jennings Bryan quite as directly and definitely as upon *Pithecanthropus erectus*, but all the effect has been (so far as he individually is concerned) confined to the development of his own person and political ideas. But since mental and intellectual adjustments may be made much more readily and promptly than can structural changes, the fact that changes have taken place in both cases is really the critical

[1] -ary, "Standard Dictionary def. 1, "connected with or pertaining to."

detail, rather than the exact period covering the changes induced as responses to environmental influences themselves not fixed or constant. Animals and plants undergo growth, climax and decline in their development from inception to extinction, and the same sequence may be traced in the example of political evolution just cited.

The biographical sketch in the New International Encyclopedia may be used as an unbiased basis for the events of the party activities of the man under consideration, and from this we learn that he came to public notice first as congressman for the district of Lincoln, Nebraska, during the silver agitation, 1891 to 1895, when his skill in oratory was turned toward the protective tariff and free silver. Response to environment was evident in the strengthening of his views along these two lines, for with the closer geographical relations he enjoyed toward the miners and mine-owners of silver, due to his residence in Nebraska, as contrasted to that likely to have been experienced by him had he remained in his native state of Illinois, he soon became one of the chief advocates of the "16 to 1" idea. As a Democrat, he was in harmony with his party concerning a tariff for revenue only, but as an individual in that party he responded (along with many others similarly situated, of course) to the local conditions developing in the Mountain States, where the development of silver mines had gone forward extensively, while cattle-raising had been developed in the nearby prairie states by similar groups of hardy citizens.

From a raw congressman, in 1891, to the Silver-tongued Orator of 1896, Mr. Bryan manifests the response of evolutionary influences in developing (rather than seriously modifying) tendencies already present, so that the "Crown of thorns and cross of gold" key-note of the Chicago Convention marked the climax in active constructive development in the political ideas of the individual who delivered that oration, as due to that particular group of influences. From that time for several years his attitude was one of defense of his views, or at least of presenting them in contrast to those of the opposite group of gold standard advocates. Organisms do not show readjustment immediately to changes in environment, and organizations made up of such complex organisms as are human beings in political party groups are not more prompt in principle than are lower forms. Economic adversity brings forth various crops of panaceas, some of which may persist for a considerable time as popular cries, even if without real value as curative measures. The western states, in which a considerable amount of the adversity in the years 1880 to 1890 was felt, were also the states in which silver was the important mining metal; if only this source of wealth could be unharmed, all would be well!

By 1895 this idea had developed to a war cry, and at the Chicago convention, July, 1896, free coinage of silver at 16 to 1 was the chief plank of the Democratic party platform and was endorsed with cheers by the Populists and by the National Silver Party in their respective conventions in St. Louis three weeks later. Mr. Bryan had become the champion of three parties differing in all essentials except the one common plank of Free Silver Coinage—an experience as a political candidate duplicated by none other in American history, since party lines have been sharply drawn.

In the development of living organisms time is a factor which needs to be considered but little, except for purposes of studying the record of their successive stages, for nature carries no watch, and is in no rush for subway or other short cuts to destination. Generations of biological types succeed each other in their slight modifications from the average form, as century passes into added century, and only the early and the late forms may show definite differences even then. In the case of political parties, made up of human beings and their ideas, the time factor is greatly accentuated, for volition, intent and intelligent direction combine to hasten any changes in either the environment or the living units upon which the environment may act. Evolution is a slow process among nature's own forms, but may be a rapid one among social beings of human grade intelligence.

One of Spencer's suggestions as to the development of the present population of the earth in biological forms is commonly expressed as "the survival of the fittest" which carries with it the corollary—"elimination of the unfit." In human society, the various forms of charity, the great range of occupational opportunities and the substitution of financial means for "fitness" in strictly competitive fields makes the application of this phrase often seem ridiculous, and to throw doubt upon its application in nature as a whole. Mr. Bryan as candidate for the presidency in 1896 for three political parties was at the climax point of his evolutionary development. The formative influences which had been developing his oratorical powers as a congressman just then reached their culmination, and his apparent fitness was recognized by the open endorsement of the parties whose candidate he became. But in the test against judgment of the population at large in the country, he was found unfit for the highest office of the land, and another case of success for the standard, defeat for spectacular form or individual was recorded. This is simply duplicating in social life of man what has occurred many times with lower animals, as with snails, for example, which have in different genera passed from simple through complex structures, only to complete the history by the survival of the inconspicuous and inelaborate forms of the original type.

Living things are able to continue to live under changing conditions because they can adjust themselves to the changes they experience, and they manifest evolution as they show in behavior or structure various adjustments to the changing environments. Mr. Bryan is a living being, he is influenced by the conditions under which he maintains his existence, even though he tries to find the most congenial of such conditions by changing from Illinois to Nebraska and thence to Florida as a place of residence and field of activity. In 1900, as he still lived in Nebraska, next door to the silver lodes of the Colorado mountains, he still advocated "Free Silver," though his associates in the convention forced him to divide his energies between this and "Imperialism," against which the chief plank was framed at the Indianapolis convention. But the country was not now in the condition of hardship that had given birth to the earlier cry, and "free silver" could not displace the "full dinner pail" as a call for voters in a nation through which prosperity was generally distributed. The Bryan factor in this campaign was possible through the holdover influence of past environment influences, just as with plants and animals; adaptations developed under particular conditions are not necessarily discarded when conditions are modified even to a striking degree, such as bringing a spiny cactus into a standard greenhouse—it still is a cactus. Having developed to his political blooming under "free silver" adversity, the peculiar twists of development continued present, even though prosperity displaced adversity in the valley of the Platte as elsewhere in the states. As an energetic editor in a growing city of a great agricultural state, Mr. Bryan kept in touch with conditions for another four years. But literary antennae and journalistic otoliths were not sufficient to keep the silver-tongued orator in the position of leader for his party, and the convention of 1904 was so fully in tune with the country-wide prosperity that it definitely defeated the nomination of the western candidate and accepted one from the capitalistic and gold-standard region of New York in the person of Judge Alton B. Parker.

Four years more of the full dinner pail and general farm prosperity brings the date of 1908 to the calendar, and the recent developments of government oversight and control were much along the lines of the imperialistic tendencies against which the Democratic party had so loudly shouted in 1900. Bryan responded to the continued influence of the anti-imperialistic attitude of his own party leaders as well as tending to develop this into an effective weapon for campaign purposes, but found much of his thunder lacking in rumble because of the vigor of Roosevelt in curbing great trusts. Bryan as Democratic candidate made less stir than did

Hearst as Independent and was allowed to return to Lincoln after Taft's inauguration to resume the editorship of the *Commoner*. This period in his political life illustrates the general condition noted among plants and animals in many cases, that when the conditions under which they are kept are changed frequently, but not greatly in any case, little definite adaptation takes place toward any one of these, but an average—which approaches the former general condition—among the possible responses is found which serves as developmental factor for the organism. After the "free silver" period had been superseded by later prosperity, the absence of any real issue upon which to challenge the country at large acted upon the potential leadership of Mr. Bryan much as a period of minor fluctuations of environment on other domesticated animals—he just dropped to the general level of the average.

The country as a whole had been under more nearly uniform influences after 1900 than for a very long period before that date, and had come to stand for similar ideals as to political and business activities in both the great political parties. So that when the Democratic Convention of 1912 was called in Baltimore, there was less to choose between as to the platform and candidate of one or the other party than at most such occasions. By obstruction, rather than by support, Bryan at this convention controlled the balloting until the nomination of Woodrow Wilson was made after other candidates had been one after another withdrawn during forty-five ballots. But no definite influences had been working upon the political field during the decade, and neither the Republican nor the Democratic party had a platform which had direct appeal to the people by contrasting principles or panacea suggestions. The general principle of government oversight of great enterprises was accepted by the leaders of both parties, and new ideas were few.

Mr. Bryan, under these conditions of general prosperity for all parties, behaved just as other forms of life have done in repeated eras of geological history—when the living conditions assume a relatively fixed character, diversities and new developments drop to a minimum, as compared to periods when rapid changes of land and water areas, with the accompanying changes in temperature of both terrestrial and aquatic habitats, stimulate adjustments to meet such changes among plant and animal forms, which we call new species. During the period from the surrender at Appomattox to 1895 the political and economic conditions of this country (and others) were undergoing great changes, the several steps of which followed in quick succession. The opening of the great western plains and prairies to settlement, the development of mining in the mountain area, and the stimulus to speculative expansion these factors gave

the country, all acted as environmental changes upon the political organism, and the parties of the nation, with their several champions, responded with rapidly developed adjustments. New political parties, with various panaceas for the unbalanced economic conditions which resulted from the over-stimulus of western resources, came upon the scene, just as in geological eras new types of plant or animal appeared when conditions changed in any great degree from those of previous periods. In the geological record, we find in any of the several periods some type dominant over others, the dominant form being for the time better fitted to the living conditions existing than are the older forms. But characteristic or briefly dominant as such forms may be for their several eras, not all are so fortunate as to leave a creative impress upon later development, even of their own type of organism. The Trilobite is a good example of this, for it developed to a dominating position by the middle of the Ordovician period, when it was not only numerous but elaborately ornamented, indicating a surplus of energy beyond that required for mere living conditions. Its decline was, however, rapid and the "Horseshoe Crab" is the only form in any appreciable manner resembling this group of ancestors, of the modern crustaceans. In the field of political history, we find individuals and parties at critical times coming into active being, championing one or another structural detail from the possible panaceas for real or imagined ills, and individuals arising with the elaborate ornamentation of vigorous health and ready response to environment acting on the general nature of the organism to develop a new species among the less well-differentiated run of the general forms. But when the conditions, the stimulus of which was responsible for the development of such spectacular forms, themselves become adjusted to later changes in geological history or in national politics, then the striking examples of evolution which may have marked the period just preceding, drop into the background, become unimportant as to their characteristics, and finally disappear as active factors in further history.

With the evolutionary forces of the last forty years acting upon a human brain, rather than upon unintelligent animal forms, the time required for changes has been but a small fraction of normal. But the fact of evolutionary response to such environments can hardly be denied in such a case, any more than in the case of Eohippus, as he adapted himself to the increasingly hard forage plants and dry ground which defined the next step in his progress toward a full grown horse.

Mr. Bryan reached the climax of his career when as candidate for the presidency in three political parties at the same time, he ran as Free Silver champion in 1896; his climax was not a sharp peak of popularity, however, and the decline curve is quite gentle until general prosperity in the west as well as in the east made the interests of the two sections more in harmony. As in so many instances of distribution a revival of development or of influence is noted after the main climax has passed, so in 1908 Bryan showed his vitality by being nominated on the Democratic ticket to run with Kern against Taft and Sherman. But he did not fit into his environment—as judged by the votes of the people—and the Silver-tongued Orator of the Platte was returned to editorial desk of the *Commoner,* while a candidate fitting more closely the new conditions of the country's rapid development went to the White House.

Extinction has come to many forms of plant and animal life because of the retention of adaptative structures beyond the time during which they were of direct service to the organism concerned. The saber-toothed tiger did splendidly for many a century when the long canines were the best aids to good living yet devised, but even these at last proved to be too much of a good thing, and he seems to have starved to death by the over-development of these very teeth, barring food from his jaws.

In the case under consideration, the climax in misfitness came when, as secretary of state, an adjustment from the promulgation of treaties of arbitration to an active attitude toward atrocities was found impossible and the very ideas which under slightly different form had been the chief factor in his policy became the disqualifying detail under pressure of actual emergency. Resigning from his post because he no longer even approximately "fitted" his environment, the one-time champion of "free silver" dropped to the background of his party and devoted his energies to newspaper activities and the lecture platform.

Agitation concerning the teaching of evolution of animal and plant forms seemed to this fluent orator as good a field for his activities as had the "free silver" and related ideas twenty years before. Unfortunately, the orator did not first become familiar with his subject, but took at second hand or even less directly the points which he used in his flowery flights of denunciation. Using his own judgment as a sufficient basis for statement and disregarding the applications of the principles of adaptation among plants and animals, of which there are scores of instances among the plants and animals of the western prairies, both in wild life and farm products, Mr. Bryan simply harangues in catch phrases of much sound but

little sense, judging from reported utterances. (As when he compares the "milk" of cocoanut, of milkweed and of cows, as a challenge to show evolution!)

Evolution is simply the unfolding and developing of capacities and adaptations in plant and animal forms under the influence of changes in the conditions under which one or another may be living. Mr. Bryan has undergone similar influences during his political career, and he would be among the first to question the statement that he had not shown responsive adaptations to these changing conditions; that is, to have manifested "evolution" in his own political development and personal history. His long political life has made possible a greater manifestation of evolution of this kind than falls to the lot of most men, but the response to environment is quite as truly present as if he personally believed in the biologist's theory and could cite examples galore.

THE READING OF GRADUATE STUDENTS[1]

By Professor RAYMOND PEARL
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IN theory, at least, that special kind of intellectual activity which we call graduate study and in so doing emphasize the least important of its milestones, should give its practitioner a comprehensive, justly balanced and critically related knowledge of the particular field whose charms have seduced him. Perhaps I ought more precisely to say that this was the theory in my youth, and is still clung to by some. But the prevalence and power of this view are unmistakably diminishing. This is perhaps chiefly because of the closer and closer integration of the advanced and graduate activities in our universities with the rest of the highly formalized and mechanized system of education which prevails in the land and is in such perfect accord with the cultivation of that efficient, standardized mediocrity which seems to be the very spirit and genius of American civilization. It is now quite possible, in fact it probably has been done, for a boy to go straight through from his letter blocks to his Ph.D. with precisely the same kind of cooperation in the enterprise on his part that a sardine furnishes to the business of his translation from the state of innocence and freedom of his birthplace to the diploma-bearing tin on the grocer's shelf. All that is requisite is a certain self-effacing conformity to a series of propulsive mechanisms.

Perhaps this is as it should be. Certainly he is a rash person who attempts to stand athwart the current of his civilization. But without being so extreme in the matter as this would imply the idea still somewhat widely prevails that, without interfering in any important way with the smoothness of the established methods of manufacturing doctors of philosophy, and without curtailing the output of this commodity, it is desirable, and should be possible, to make the *graduate* student take a more active personal interest in the process of his transfiguration than the sardine may be presumed to. During the quarter of a century that I have tried to function as an insignificant cog in certain of the mechanisms referred to, the problem of how best to make those machines more useful has intermittently but still extensively engaged my attention. The instinct of workmanship is fairly deep-seated. We all like to do as good a job as we can. It has fallen out that my duties

[1] Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University. No. 116.

have been mainly to aid in the progress of graduate students along their appointed chutes. The problem has been: How may that basic ideal of graduate instruction stated in the first sentence of this paper best be promoted? Not solely by lectures, it is generally agreed. There are two fundamental objections to this method; the first that it would make insufferable inroads on the professors' diversions, the other that it tends to perpetuate the intellectual inertia begotten in the student's undergraduate course.

The only other way yet heard of to accomplish the end sought is that known as directed reading. The instructor is supposed to outline a course of reading for the student which will make him privy to at least the major secrets of his subject. The advantages of this method are obvious. The student does something for himself. At its best he gets the sense of professional craft solidarity. He becomes really initiate into the realm of scholarship and makes contact with the great minds that have built the structure whose architecture he must know before he can add his bit to it. At the worst he has satisfied a requirement of the manufacturing process with a minimum amount of trouble to his instructor.

But granting the fundamental soundness of the pedagogical device of directed reading for graduate students, there still remains the problem for the instructor of determining on a general principle for the guiding of this reading. Obviously the student can not read in the three years of his graduate study as much of his subject as the instructor has in the, let us say, n years of his professional life. A selection must be made from the treasures at command. But upon what principle shall this selection be made? It is this question which has vexed my mind, and I fancy that of many another in similar position. What I used to do was to make out lists of highly technical researches in the particular field of interest and tell the student that along that pathway was the road to salvation. This I am sure was a mistake. It started from a false assumption. The progression was forthwith to the special on the supposition that the general had been taken care of. But nothing could be more ridiculous nonsense than such an assumption. In consequence of the widely prevailing pedagogical theory that needlework, jigsawing, salesmanship and many other kindred academic disciplines are of at least equal cultural and intellectual value in the training of our youth to the study of Greek or Latin or mathematics or chemistry; coupled with the permission, if not active encouragement to the undergraduate to specialize during his mental infancy, it results that when the young things begin serious graduate work a solidly grounded general cultural background upon which to build a sound specialism is precisely what, generally speaking, they most completely lack.

What then to do? Plainly the obligation is to repair as much as may be of the damage that has been wrought from omission and commission, by putting in the way of the student the means of orienting himself relative to his subject on the one hand and to the general *corpus* of human learning on the other hand. If he is any good—I mean any *real* good—he will then guide himself to the technical reading in his chosen special subject better than any one else can do it for him. If he is not any good—I mean again any *real* good—no harm will have been done. He will at least have glimpsed some little part of the evidence that

> Man's mind a mirror is of heavenly sights,
> A brief wherein all marvels summèd lie,

and in all probability will ever after lead a better life, even though he fails to become much of a biologist or biometrician.

After thought, and the application of the method of trial and error, I have evolved the course of reading for my graduate students which it is the purpose of this paper to exhibit. At the outstart it should be explained that the students for whom this list is primarily designed are looking forward, for the most part, to careers connected in some manner near or remote with public health. Mainly they want to become qualified vital statisticians or biometricians. Some regard academic halls as the optimum environment for their souls' ultimate expansion; others look forward to a career of usefulness in an official bureau or an independent research institution. All intend, bless their innocent hearts, to become investigators, researchers, small or great as *Allah* may will, but anyhow members in good standing of the holy brotherhood of those curious to know. All these considerations have played their due part in the making of the list. But what has been of the greatest importance in determining its final constitution is that public health, vital statistics and biometry are all, when properly viewed, parts or branches of *biology*. Naturally, if one were making such a list for an embryo physicist or chemist some of the items on the present would be replaced with others more directly pertinent to those lines of endeavor. But not all would be so replaced. A certain philosophical generality which taints and savors the list as a whole is perhaps its most engaging feature. Just as it stands it would do no harm to the graduate student of zoology or botany, particularly if he chanced to be interested in the problem of organic evolution. In fact, the student of evolution generally would be a good deal better off if he knew more about vital statistics than, except in rare instances, he now does.

The list is divided into three main parts on the following philosophy. Any person who intends to make his living and to spend

his life at science plainly ought first of all to have the clearest possible understanding as to what science is and what it is all about, in a broad philosophical and *human* sense. Such an understanding should come early in the course of professional scientific study. Perhaps the student is embarking on a scientific career under a misapprehension as to what science really is. Such cases have been known. They are always sad and may be tragic. Hence Section A, "The Nature, Meaning and Method of Science."

Because a person, from however pure and noble motives, elects to be a worker in science he is not thereby absolved from the duties and privileges of being human. He must work out an adjustment between the claims upon his life of his science, a proverbially jealous and exacting mistress, and those of the rest of the world, including not only deans, committees, commissioners, directors, boards, foundations and other great cosmic elements, but also cooks, maids, nurses, children and most important of all, his wife. While no one else can make these adjustments for him, still it will help to know how others have met the problem. Again if our graduate student, in whose behalf we are taking all this trouble, turns out to amount to much he will sooner or later receive offers for the purchase of his soul. Such offers will be made by those skilled in the traffic and they will be tempting. A little knowledge of the technique in these matters will not be amiss. Shall we not be derelict in our job of helping our student to get his training for life if we do not furnish him some insight into what wisdom is available about the making of these necessary adjustments between scientific research and the rest of life? I think so. Hence Section B, "The Conduct of Life."

Finally, and more obviously, my student is going to earn his living by the practice of a particular scientific trade. Hence Section C, "Vital Statistics."

I attach great importance to the order of the several items in the list. The maximum effect will be produced by reading them in precisely the sequence in which they are here set down, I believe.

(A) The Nature, Meaning and Method of Science

(1) Lucretius. *De Rerum Naturae.* Since few persons in this day and age can by any chance read this great poem about the problems with which science deals in the original Latin, I hasten to point out that certainly the handiest and perhaps on the whole the best translation for the purposes of the student of science not interested in the *minutiae* of textual criticism is the one published in Everyman's Library. (New York; E. P. Dutton & Co.).

(2) Seneca. *Quaestiones Naturales.* Undoubtedly the best translation for our purposes of this classic by a great man, who fur-

nishes the first example in a long series of the dreadful consequences of mixing science and politics, is that by John Clarke, entitled "Physical Science in the Time of Nero," London (Macmillan & Co.), 1910. The translation is intelligently accurate, and the edition is enhanced in value by the notes of Sir Archibald Geikie.

(3) ARISTOTLE. *Historia Animalium.* Beyond any comparison the best translation of this biological classic is that by D'Arcy Wentworth Thompson, which forms Volume IV of "The Works of Aristotle. Translated into English under the Editorship of J. A. Smith and W. D. Rose." Oxford (Clarendon Press), 1910. From the present point of view it is a pity that the annotations on biological matters are so meager in comparison with those on textual points, in this otherwise excellent edition. Gordon Alexander has recently (*Science,* March 13, 1925) called attention to a French translation of the *Historia Animalium* by Armand Gaston Camus (published in Paris, 1783) which supplies, by extensive biological notes, the deficiency mentioned in D'Arcy Tmompson's translation.

(4) LAWRENCE J. HENDERSON. *The Order of Nature.* Cambridge (Harvard University Press), 1917. This brief but important treatise will make it clear to the student, if it is not already so, why he has been asked to read the three preceding references. Further it will acquaint him early with *the* fundamental problem of science.

(5) LUCIAN OF SAMOSATA, *Vitarum auctio* and *Piscator.* These dialogues are included at this point to aid the student in properly orienting himself in respect of the rather weighty philosophical matters that have constituted so large a portion of his *pabulum* up to this point in the proceedings. He will find Lucian's account of the auctioning of the creeds, and its consequences, an agreeable corrective to any tendency towards mental coarctation or impedition which may have developed. While I refer here specifically to but two of Lucian's works, it is always to be hoped that this sample will whet his appetite for more, and that the student will read this too much neglected author extensively. Regarding translations I can recommend as the raciest rendering of Lucian in English "The Works of Lucian of Samosata." Translated by H. W. Fowler and F. G. Fowler. 4 Vols. Oxford (Clarendon Press), 1905. The volumes are of a handy size, and I find I take it from my library shelf oftener than any other edition of Lucian. Its only fault is a somewhat heavier expurgation than robust biologists will find necessary.

The works listed up to this point may fairly be said, I think, to expose within their limits the field of science as a whole in its philosophical meaning and relationships. He who has read through

these five titles can not fail to be impressed with the nobility and grandeur of the enterprise upon which he has embarked in deciding to devote his life to science.

We may next properly consider in some detail, but also with generality, the *method* of science.

(6) FRANCIS BACON. *On the Dignity and Advancement of Learning* and *Novum Organum; or True Suggestion for the Interpretation of Nature.* Our student will talk and hear a great deal about the Baconian method. It is reasonable that he find out at first hand what it is. Also his eyes will be helpfully (and widely) opened in various other directions by reading these two books.

(7) RENÉ DESCARTES. *Discours de la méthode pour bien conduire sa raison et chercher la vérité dans les sciences.* This great classic on the method of science has been translated into many languages. The student may read it in any he likes.

(8) WILLIAM WHEWELL. *The History of the Inductive Sciences.* While never, so far as I am aware, characterized as light reading, there is nothing to this day to take the place of this treatise. A supplement or sequel to it ought to be done. It formed in Whewell's own mind only the first half of his *magnum opus,* but I have never had the courage—even if I had had the desire—to ask any young and cheerful student to wade through that preternaturally dull and in good part quite unsound book, "The Philosophy of the Inductive Sciences, formed upon their History." It may be said, however, that there is a certain amount of entertainment and profit to be derived from the "Aphorisms" in Volume II.

(9) GUSTAVE FLAUBERT. *Bouvard et Pécuchet.* This I conceive to be one of the most important titles in the whole list. Its outlook on life and learning is *essentially* that of "The Education of Henry Adams," but it is a much more entertaining book. And at just this point, after the very solid meat of Whewell, something in the nature of an acation is needed.

(10) KARL PEARSON. *The Grammar of Science.* I like best the second edition. I am told by some of my friends that this is not a great book, that it lacks originality and fails in other ways I can not now remember. Perhaps so. I first read it the year I began graduate work. It produced at that time such an effect on my intellectual outlook as no other book I had ever read. Henry Adams reports that Willard Gibbs said he found it helpful. I know of no other single book quite so important for the student beginning graduate work in science to read.

(11) F. C. S. SCHILLER. *Formal Logic, a Scientific and Social Problem.* London (Macmillan & Co.), 1912. Logic is a necessary part of the methodological equipment of the man of science. But it is in some respects the most tricky and dangerous tool in the box. Schiller is a sound guide.

Most of my students look forward to a lifework in a universe of discourse in which the chief objective realities will be medical and biological matters. On this account it seems reasonable that they have a glimpse at least of certain philosophical and historical aspects of these fields.

(12) GALEN. *On the Natural Faculties.* Every medical student hears of Galen. Few read him. The most satisfactory edition readily available is that in the Loeb Classical Library, the translation being done by a medical man, Dr. Arthur John Brock.

(13) ARTHUR TILLEY. *Francois Rabelais,* Philadelphia (Lippincott), 1907. This book is an intercalation which theoretically ought not to have to be here. It is inserted simply as a preparation for the next item on the list. Many persons find it difficult to get anything like a proper appreciation and respect for the significance of Rabelais in the history of thought when they approach his works wholly unprepared. One needs to know something of his times and the circumstances of his life. Tilley's commentary is sound and helpful.

(14) FRANCOIS RABELAIS. *Five books of the Lives, Heroick Deeds and Sayings of Gargantua and his Sonne Pantagruel.* Of this great classic there are innumerable editions. In the original it is difficult for any one not a specialist in medieval French. But the English translation begun by Sir Thomas Urquhart and finished by Pierre Motteux has become a classic on its own account. Of the various editions in my collection I will mention only these: First the Navarre Society's two column edition recently issued, with illustrations by W. Heath Robinson. To those who know Rabelais and Heath Robinson further comment is unnecessary. The typography and printing of this edition are beautiful. But the volumes are too bulky for the travelling bag, and the edition lacks Motteux's notes which are valuable. For everyday use I find a little five volume edition published in London, edited by Alfred Wallis, to be very convenient.

(15) WILLIAM HARVEY. *An Anatomical Disquisition on the Motion of the Heart and Blood in Animals.* The Everyman edition is excellent.

(16) WILLIAM MADDOCK BAYLISS. *Principles of General Physiology.* Probably there is no other single book which so wisely, justly and philosophically sets forth what is known of the general principles of biology. I like best the original edition.

(B) THE CONDUCT OF LIFE

(17) ARTHUR SCHOPENHAUER. *Parerga und Paralipomena.* In this collection of essays the one especially referred to here is *"Aphorismen zur Lebensweisheit."* Selected papers from this col-

lection were translated by T. B. Saunders in his "Essays of Schopenhauer." The most important parts, for the present purpose, of the *Lebensweisheit* are given in this translation as "The Wisdom of Life" and "Counsels and Maxims." In steering a pleasant and successful voyage through the tortuous and perilous channels of the sea of life in the real world of to-day the student will find few guides so sound and practical as this essay, because it will clarify his vision as to where the perils lie. It is of course to be hoped that this introduction to Schopenhauer will tempt the student to read his great contribution to philosophical thought *Die Welt als Wille und Vorstellung.*

(18) H. L. MENCKEN. *Prejudices.* Series I to IV inclusive. New York (Knopf). Along with some matter perhaps irrelevant to the present purpose these essays contain much ripe wisdom about the more important aspects of the technique and ethics of civilized living.

(19) *Jerome Cardan—The Life of Girolamo Cardano, of Milan, Physician.* By HENRY MORLEY, London. (Chapman and Hall), 1854, 2 vols. In building up a useful working knowledge of human behavior there is much in favor of the same pedagogical method that has been found so valuable in other branches of zoology, namely, the careful study of type specimens. The short series which can be included here starts with Cardan. He was, on the whole, probably the most distinguished mathematician and the most distinguished physician of his day. This combination should interest the budding biometrician. His life was quite as melodramatically thrilling as that of Benvenuto Cellini.

(20) *Memoirs of the Life, Writings and Discoveries of Sir Isaac Newton.* By Sir DAVID BREWSTER. Edinburgh (Constable), 1855. 2 vols. Two individuals more completely unlike in certain respects than Cardan and Newton probably never existed. But in certain human reactions to their work they were very like indeed.

(21) *Memoir of Augustus De Morgan,* by his wife, SOPHIA ELIZABETH DE MORGAN. London (Longmans, Green), 1882. The reasons for inserting this and the next few items are so obvious as not to require comment.

(22) HUGH MILLER. *My Schools and Schoolmasters, or the Story of my Education.* My copy is of the 13th edition, and dated Edinburgh 1869. To our mentally and financially becoddled fellowshippees of the present day this book must seem like some prehistoric fairy tale.

(23) *The Life and Letters of Charles Darwin, Including an Autobiographical Chapter.* Edited by his son FRANCIS DARWIN. 3 Vols. London, 1887. If this life, with its perfect devotion to the

highest ideals of science, does not prove an inspiration to the student, he is hopeless.

(24) *Samuel Butler Author of Erewhon* (1835–1902). *A Memoir by Henry Festing Jones.* London (Macmillan), 1919. 2 Vols.

(25) *Quetelet—Statisticien et Sociologue.* By J. LOTTIN, Louvain and Paris, 1912.

(26) FRANCIS GALTON. *Memories of my Life.* New York (E. P. Dutton & Co.), 1909.

(27) KARL PEARSON. *The Life, Letters and Labours of Francis Galton.* Vol. I. Birth 1822 to Marriage 1853. Cambridge (University Press), 1914. Vol. II. Researches of Middle Life. Cambridge (University Press), 1924. This great biography by Pearson is inserted in this list in addition to Galton's own autobiography because of its very great technical value to the biometrician. It contains a wealth of suggestive ideas.

(28) RENÉ VALLERY-RADOT. *The Life of Pasteur.* Easily available in either French or English.

Room lacks for more specimens of really sapient human beings. There are many other matters which must be covered in this reading list. But one always hopes that these few choice samples will develop a taste for biographical reading. We turn now to other considerations.

(29) ANATOLE FRANCE. *Le mannequin d'osier.* Our student may have thoughts of a career as a college or university teacher. He ought to know something of the inwardness of such a life.

(30) WILLIAM MORTON WHEELER. *The termitodoxa, or biology and society* (SCIENTIFIC MONTHLY, February 1920, pp. 113–124) and *The dry-rot of our academic biology.* (*Science,* Vol. 57, pp. 61–71, 1923.) These two items have the same purpose in our scheme as the preceding, No. 29.

(31) FRANCOIS MARIE AROUET DE VOLTAIRE. *Micromegas.* This should be read frequently—it is short—from youth on, as a powerful protection against the ever-present danger of becoming seriously important—or importantly serious. This peril threatens all mankind, but especially professors and public officials.

(32) JAMES BRANCH CABELL. *Straws and Prayer-books. Dizain des Diversions.* New York (McBride), 1924. To the end that the student may observe the working of the mind of an artist, and see the great similarities and small differences between original creative effort in art and in science.

(C) BIOMETRY AND VITAL STATISTICS

(33) CHARLES DARWIN. *The Origin of Species* and *The Descent of Man.* No better introduction than these two books to the mode

of reasoning fundamental to sound statistical procedures can be found.

(34) WILLIAM W. KEEN. *I Believe in God and in Evolution*, and *Everlasting Life; a Creed and a Speculation.* Philadelphia (J. B. Lippincott Co.). These two books should be read immediately after Darwin. The student will see how a sincere and orthodox religious faith may be brought into the fullest reconciliation and harmony with the latest developments of science.

(35) JOHN GRAUNT. *Natural and Political Observations Mentioned in a following Index, and made upon the Bills of Mortality.* 1662. The first treatise on vital statistics. For student reading the extremely well-edited and annotated reprint of this classic in C. H. Hull's "The Economic Writings of Sir William Petty, etc." 1899, is the edition of choice.

(36) T. R. MALTHUS. *Essay on the Principle of Population as it Affects the Future Improvement of Society.* 1798. The Everyman Library edition, which is a reprint of the seventh edition of the original work, is excellent.

(37) A. N. WHITEHEAD. *An Introduction to Mathematics.* New York and London (Home University Library), 1911. This little treatise has served admirably two useful purposes in my laboratory ever since its appearance. First to dispel mathematicophobia when present, and second to demonstrate to the average student fresh from undergraduate mathematics, as taught in our colleges and universities, that the intellectual content of that subject extends beyond puzzle-solving.

(38) ISAAC TODHUNTER. *A History of the Mathematical Theory of Probability from the Time of Pascal to that of Laplace.* Cambridge and London (Macmillan & Co.), 1865. To be regarded, in all reverence, as the Bible (revised version) of the subject.

(39) CHARLES S. PEIRCE. *A Theory of Probable Inference.* In Studies in Logic by Members of the Johns Hopkins University. Boston, 1883, pp. 126–181. This is a classic. No student of statistics can properly be said to have laid his basic foundations till he has mastered this essay.

(40) WILLIAM FARR. *Vital Statistics: A Memorial Volume of Selections from the Reports and Writings of William Farr, M.D., D.C.L., C.B., F.R.S. Edited by Noel A. Humphreys.* London, 1885. This may profitably be supplemented by delving in the Registrar General's Reports, because Humphreys by no means extracted all the meat from the writings of the greatest medical statistician who has lived.

(41) FRANCIS GALTON. *Natural Inheritance* and *Inquiries into Human Faculty and its Development.* Two great statistical classics.

(42) LAHMAN FORREST BROWN. *The Economic Waste of Sin.* New York (Abingdon Press), 1924. This book is introduced in

order that the student may study a nearly perfect specimen of a significant modern, indeed post-war, development of statistical "science,"* namely, the use of what is conceived to be the statistical method in the *service* (*sensu Rotarianismo*) of humanity, to uplift us all, help us to lead a purer and nobler life and in general do somebody good. All present signs indicate that this branch of statistics offers by a considerable margin the most lucrative career of any in the profession. As its technique is but little taught in the higher seats of learning perhaps it is only fair that the student should be directed to a prize example.

(43) KNUD FABER. *Nosography in Modern Internal Medicine.* London (Oxford University Press), 1923. An excellent brief history *not* of medicine but of medical *ideas.*

(44) ERWIN BAUR, EUGEN FISCHER, FRITZ LENZ. *Menschliche Erblichkeitslehre.* München (J. F. Lehmanns Verlag), 1923. That the student may know something of the modern science of genetics in its relation to man.

(45) JULIUS BAUER. *Die konstitutionelle Disposition zu inneren Krankheiten.* Berlin (Julius Springer). That it may become even clearer that genetics has relation to medicine.

(46) WILLIAM G. MACCALLUM. *A Text Book of Pathology.* Philadelphia (W. B. Saunders Co.). So that if our student becomes a practicing vital statistician he may have a less vague notion than he otherwise might of the objective realities which lie behind the statements as to causes of death which appear upon death certificates.

(47) WILLIAM TRAVIS HOWARD, Jr. *Public Health Administration and the Natural History of Disease in Baltimore, Maryland, 1797–1920.* Washington (Carnegie Institution, Publication No. 351), 1924. To the end that the time base and other elements of his thinking about public health problems may be expanded, if by chance our student is interested in public health.

(48) G. UDNY YULE. *An Introduction to the Theory of Statistics.* Seventh Edition. London (Griffin & Co.), 1924. This book ends the list, not because the student will not have made contact with it sooner, but because it will be desirable to reread at this terminal stage a book which in my judgment embodies and exemplifies, in a degree that no other I know of does, a sound, well-ripened philosophy of the statistical method.

Little needs to be said in the way of epilogue. Doubtless this list of reading will be violently criticized by some. But so probably would any other list. The real test of its value is the effect which the reading of the books in it produces upon the minds of graduate students. As to the outcome of such a test I am not greatly worried.

* So to speak.

THE NEW IMMIGRATION LAW AND ITS OPERATION

By Professor ROBERT DE C. WARD
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WHAT were the objects of the immigration act of 1924? How far are those objects being accomplished? What changes or improvements are suggested by our experience with the operation of the new act since July 1 last?

The main provisions of this law may be classified under three heads, *viz.*, (1) limitation of numbers and allotment of the quotas; (2) preliminary selection overseas; (3) provisions based on humanitarian motives.

(1) LIMITATION OF NUMBERS AND ALLOTMENT OF QUOTAS

The annual quota (until June 30, 1927) is 2 per cent. of the number of foreign-born of each nationality in this country in 1890. This allows between 160,000 and 170,000 new alien immigrants to come in annually, by far the majority of them from Europe. Immigrants born in countries of the western hemisphere and their wives and unmarried children under 18, if accompanying or following them, can come in without limitation as to numbers provided they are not excludable on physical, mental or moral grounds under the general immigration act of 1917.

The first quota act, that of 1921, now superseded, limited immigration to 3 per cent. of the foreign-born living in the United States at the time of the 1910 census. This gave the countries of southern and eastern Europe, together with Asiatic Turkey and Palestine, nearly 50 per cent. of the total immigration, although the natives of those countries now in the United States constitute only about 15 per cent. of the total white population. The 2 per cent. percentage provision in the new law (using the census base of 1890) gives southern and eastern Europe and near-Asia roughly the same proportion of the total immigration as the natives of those countries now in the United States bear to our total population. Yet certain groups composed of recent immigrants from southern and eastern Europe are demanding larger quotas on the ground that they are not getting a "fair share" of immigration. They claim that the present immigration law "discriminates" against them. If the percentage law can be said to discriminate at all, *the element against*

which there is discrimination is the native-born American, for the quota percentages, it must be remembered, are based solely on the numbers of *foreign-born* in the United States in 1890. This law recognizes the fact that, if racial interests are to be considered impartially, the native's natural preference for his own kind should be given equal consideration with the similar preference for his own on the part of the foreigner. This is proportional representation. It is a declaration that what we now are racially that we propose to remain. As Commissioner Curran has well put it, each year's immigration is to be "an exact miniature of what we are as to stock." If there ever was a sound, fair, bedrock immigration policy, this is surely such a policy. The act of 1924 is designed to keep our country from becoming any more of a "polyglot boarding-house," as Theodore Roosevelt aptly phrased it, than it already is; to maintain, as nearly as possible, our present racial *status quo;* to preserve, as best we can at this late date, something approaching racial homogeneity. Are these objects "unfair," "discriminatory," "un-American"?[1]

Certain groups opposed to restriction are insisting that this new law of 1924 was a hurried piece of temporary legislation; rushed through without adequate consideration; not representative of public opinion. Nothing could be farther from the truth. It was the outcome of a steady growth of restriction sentiment, as is abundantly evidenced by the literature on immigration during the past twenty to thirty years; by the enactment of the successive laws of 1882, 1885, 1891, 1903, 1917 and 1921; and by the report of the U. S. Immigration Commission, completed in 1910. This report, fifteen years ago, recommended restriction "as demanded by eco-

[1] Beginning with July 1, 1927, the total new quota immigration is to be 150,000 a year. The annual quota of any nationality is to be "a number which bears the same ratio to 150,000 as the number of inhabitants in continental United States in 1920 having that national origin bears to the number of inhabitants in continental United States in 1920." This is the "racial origins" provision and was suggested by Senator David A. Reed, of Pennsylvania. It cuts straight through, and ends, the controversy as to whether the quotas shall be based on the census of 1910 or on that of 1890. The quotas are no longer to be based, as now, upon the *foreign-born,* those composing the alien "colonies" and alien "blocs" now in this country, *ignoring the native-born,* but are to be divided among the different nationalities according to the national origins of our population as a whole.

This is an even fairer apportionment, if that be possible, than the one now in operation. It gives southern and eastern Europe essentially the same percentage of the total immigration as at present. On the "national origins" base, however, certain countries within each group will have their quotas changed somewhat, up or down, so as to conform, even more closely than is the case with the 1890 census base, to the representation in our present population of each stock derived from a given national origin.

nomic, moral and social conditions," and also suggested a percentage limitation. No immigration measure ever had such deliberate and intelligent consideration as was given to the new act. The overwhelming majorities by which the bill passed Congress clearly reflected public opinion. The present immigration law is not a temporary measure. It represents a permanent policy and was so accepted by the American people when passed. There is absolutely no necessity for any further investigation of immigration. Few national problems have been so completely "investigated" during the last two or three decades. There are few on which information is more complete. The limitation of immigration by means of a quota is settled American policy. The organized opposition of certain racial groups to the present law will simply confirm the American people in their belief that the act of 1924 is sound policy, and will again emphasize the fact that we have in our midst considerable numbers of un-Americanized aliens who are loyal to their own race and traditions rather than to the United States and its institutions.

The new law has successfully accomplished its two main objects. It has reduced the quantity of legally admissible new immigration to about one half of what it was under the preceding law. The non-quota contingent, which comprises aliens from the western hemisphere, relatives of aliens already in the United States, and other exempt groups, will amount to at least as many more. Taking both quota and non-quota together, immigration now averages about 1,000 a day. This is roughly about a third of the pre-war numbers. Secondly, distribution among the various nationalities is now fairly in accordance with the racial composition of our present population. This is a logical allotment, safe for us and fair to all.

Standing guard at Ellis Island, the gate through which most of our immigrants enter, Commissioner Curran has the best opportunity in the country of observing the effects of the new law. He says:

> As an affirmative performance, the immigration act of 1924 has already done great good to our country, and it gives promise of doing more. The immigrants who come to us now are fewer and better. They are cleaner nowadays. They possess better health, better intelligence, better promise of industry that produces, than did their predecessors. In the main they are outdoor folk, pink-cheeked, long of limb and muscular. They will labor rather than barter, work in the open rather than buy and sell in the alleys. They are self-contained, confident. And they are young. It is the youth of Europe that is coming through the island these days.

There is another very important point, long emphasized by those who have advocated numerical limitation and selection of immigration. By reducing our annual immigration and by increasing the proportion of immigrants from northern and western Europe, our

problems of education and assimilation are inevitably greatly simplified. We have breathing-space. We can begin to make some headway in our stupendous task of amalgamating and "Americanizing" our foreign-born. No more striking testimony on this point can be found than the statements of Mr. Bradley Buell, secretary of the New York City Council on Immigrant Education, as reported in the New York *Times*, July 17, 1924:

> By limiting the number of immigrants who will come in, the new immigration law gives organized education and social work its first real opportunity to help the foreigners already here to take a more intelligent part in the life of the city. . . . Ninety per cent. of the immigrants who have been coming here annually could neither speak, read nor write English when they came—and many live here for many years without acquiring a working knowledge of the language. Their contact with other races than their own is subject to the same kind of irritation that we have in Europe. The jealousies, traditions and prejudices of the old world have been transplanted here and will continue unless a common basis of language and ideals can be supplied by American leadership. The children learn English in the public schools, it is true, and often speak only imperfectly the language of the parents, but this frequently means that they become neither one thing nor the other—good American or good Italian, Pole or Greek—a factor entering into the high percentage of criminality among the children of foreign parents. To accomplish constructively the delayed task of assimilation is the opportunity now afforded.

(2) Selection

The new immigration act embodies the first attempt that the United States has ever made to conduct a preliminary selection abroad. Every intending immigrant must now have an "immigration visa" issued by a United States consular officer. Before obtaining this certificate the alien must present considerable proof of his good character and worth. The evidence required includes certain important documents, such as birth certificate and penal record. In addition, the law requires the immigrant's statement that he does not belong to any of the various classes excluded from the United States by our laws. The consul has the right to refuse the visa if he "knows or has reason to believe that the immigrant is inadmissible."

This new plan is not in any sense of the words a medical or general "inspection" abroad, but it is, as it was intended to be, a preliminary "weeding out" overseas. There can be no doubt that the plan is working out satisfactorily, in spite of the many cases of dishonesty and perjury among the aliens who apply for the visas. Hon. Albert Johnson, chairman of the Committee on Immigration of the House of Representatives, has said (Feb. 11, 1925), "the quality is grading up noticeably, due principally to the overseas questionnaire." While far more might be done in the careful selec-

tion of our immigrants before they embark, there is no doubt whatever that this new law has taken a distinct step in the right direction.

(3) Humanitarian Provisions

The act of 1924 goes far beyond any preceding immigration law in the provisions which it makes to diminish the hardships which our immigrants used to suffer. The preliminary selection abroad prevents the embarkation of a considerable number of aliens who would be found inadmissible on their arrival here. Further, under the former law (1921) many aliens arrived here after the quotas for their various nationalities were full. Merely because their ship was slower than some other vessel, through no fault of their own, thousands of aliens were debarred as "excess-quota" and deported. The new law has ended this unhappy situation. The immigration visas are issued only up to the numbers allowed by the quota, and are good for four months. Therefore, if an alien comes at any time within that period he can not be denied admission as being in excess of the quota. Again, the visas issued in any month may not exceed 10 per cent. of the annual quotas. This provision stops the rush of aliens at the beginning of each month and at the end of the year; and does away with the discomforts due to excessive congestion at Ellis Island. Furthermore, the number of rejections of aliens inadmissible under our laws has been decreasing, as the consuls have learned their duties and have been more careful about granting visas.

As to the admission of families: Wives and unmarried children under 18 of citizens of the United States are admitted without quota limitation, and in issuing visas preference up to 50 per cent. of the annual quota of any nationality is given to aliens who are unmarried children under 21, fathers, mothers, husbands or wives of citizens. The law thus makes reasonable provision for keeping families together. Furthermore, it should be remembered that aliens still overseas who wish to join relatives in the United States and do not fall within the non-quota or preference groups can still come in under the regular quotas, if otherwise admissible. In addition, the law makes specific provision for the non-quota admission of ministers and professors, with their wives and unmarried minor children; of bona-fide students, tourists, those coming temporarily for business reasons, and others.

In spite of the many humanitarian provisions in the new immigration law, stories of alleged hardships are constantly finding their way into the newspapers. There are reports of exclusions of individual aliens who came with consular visas and expected to be ad-

mitted for that reason, and there are pathetic stories of separated families. Most of these stories are circulated, for propaganda purposes, by organizations and individuals who are seeking to stimulate opposition to the law in order that it may be modified. It is always easy to arouse public sympathy in cases of supposed individual hardship, especially when these are presented in the lurid fashion of many of our yellow journals. Hundreds of such reported cases of hardship have been investigated by the officials of the Immigration Service, who found that there was little or no truth in them.

Again, it can not too often be reiterated that the immigrants know our immigration laws far better than we do. When the consular visa is applied for, the alien has to answer a very full questionnaire in which he is thoroughly informed regarding the causes for which he is liable to exclusion. It is safe to say that in most cases an alien excluded on arrival here knew when he received his visa that he, or the member of his family who is excluded, was likely to meet this fate. He has no grounds for complaint against the law or the United States. He knew that an immigration visa is not a ticket of admission, for he was definitely told so when he appeared before our consul abroad.

Further, in spite of the provisions for the non-quota admission of certain immediate members of the families of citizens and the preference allowed within the quotas for other members of the families of citizens, "sob-stuff" stories of separated families flood our papers. An alien now in this country wants to bring in all his European relatives and this may be impossible under the quotas. Some hyphenated organization composed of fellow-countrymen of this alien immediately takes up the case, dresses it up in a sensational and heart-rending fashion, and a yellow journal reporter writes up the story for the front page of his paper. But before becoming excited about such cases, we should remember that the United States did not separate that family. It was the family which separated itself, in Europe, when one or more of its members first came to this country. There is a widespread campaign, well organized and well financed, to have the law modified so that more distant relatives than those already provided for shall be admitted. To take such a step would break down the law completely. Everyone in Europe and near-Asia is a near relative or at least a "cousin" of someone already in the United States. If we started to lower the bars to all such relatives there would be an endless chain of quota-exempt persons. Obviously, under the present law, even the relatives now admissible, either non-quota or by preference within the quotas, can not all come here this year, perhaps, or even next year.

But it is not unfair to let them wait their turn. When we wish to travel on a limited train and can not secure accommodations, we wait for a later train. This whole situation has been clearly stated by Hon. Albert Johnson as follows:

> In the meantime it may be said that the law puts no obstacle in the way of emigration. If an alien wants to unite with his family, there is nothing to prevent such union in the country from which he came. No alien comes here except by his own initiative. Our government does not separate any alien from his family. His coming and his separation from family always are voluntary on his part, and in most cases with full knowledge of the probable difficulties. It follows that we are under no obligation to conform our governmental policies to his desires or alter our statutes to suit his convenience.

Americans must be careful not to be carried off their feet by the many pathetic tales of the "injustice" and the "cruel hardships" supposedly inflicted by our immigration law. As Mrs. Nathaniel Thayer, of the Division of Americanization of the Massachusetts State Department of Education, has so effectively expressed it, "Let your heart ache for suffering humanity, but let it beat for the United States."

(4) Additional Legislation Needed

While it is still too early in our experience with the new law to specify all the amendments which may later prove to be desirable, one thing is already certain. Registration of all aliens must be required. With the increasing restrictions which have been put upon immigration, the smuggling and surreptitious entry of aliens across our land borders and by sea have enormously increased. While most of these "bootleg" immigrants are probably mentally and physically up to the very low standards which we have set, many doubtless belong to the diseased and defective classes who should most rigidly be excluded. Secretary of Labor Davis advocates registration as an effective way of outwitting the border-jumper and the smuggled alien. Under this plan every alien would be required to register or enroll annually. Failure to register would be punishable by a fine. Registration would be carried out under the auspices of the Department of Labor. A final check-up of aliens who failed to comply with the law would naturally occur when an alien applied for his citizenship papers.

Aliens legally admitted to the United States under the (1924) law must surrender to the government all the papers they bring with them, such as passport, birth certificate, etc. Further, inasmuch as the law now places upon the alien the burden of proof as to his right to be here, he should surely have the evidence of this right which a preliminary registration on landing would give him.

Such registration would in fact be a receipt for the papers which he surrendered on his admission—a legitimate and obvious protection to him throughout the time until he becomes an American citizen. This plan would not only help in the work of assimilation and education and as an important step towards naturalization, but, what is of even more importance, it would reveal the presence of criminals, diseased, defective and other illegal entrants. If our laws against undesirable immigration are to be effective, registration of all aliens is a necessity. Again, by bringing the newly arrived alien regularly into contact with our government authorities, in the process of annual registration, we should be protecting him against those of his own nationality, already here, who are always ready to take advantage of his ignorance to exploit him for their own gain. Registration would thus be a simple act of Christian charity on our part. The requirements of registration would greatly simplify the process of Americanization and naturalization. There is no hardship or indignity in this for any alien who is rightly here. In registering aliens in the United States we should merely be doing what Great Britain, France and other liberal nations in Europe have found to be necessary for their own protection. Not to do everything in our power to fight illegal entry is to be unfair to those who, respecting our laws, patiently await their turn to come in under the legal quotas. Registration is advocated by the New York Chamber of Commerce, by the Committee on Immigration of the Eugenics Society of the United States, and by many other important bodies. Police Commissioner Enright, of New York, is on record as believing that every citizen as well as every alien in New York should be forced to carry a card containing his photograph and finger-prints, in order that criminals and other undesirable persons may the more surely and speedily be apprehended.

The successful operation of the new consular immigration visas, so far as these go, suggests a more thorough overseas investigation of intending immigrants before the visas are granted. In the development of this plan care must be taken not to conflict with treaty provisions limiting the jurisdiction of our consulates, and in any event final inspection at the point of entry into the United States must be retained. This will be necessary to guard against the danger of fraud and maladministration which may occur abroad, and also to detect cases of inadmissibility which develop, or first appear, between the time of inspection abroad and the arrival of the immigrant in the United States. Between the presentation of the alien's passport and the granting of the visa, the American consul could, if his government instructs him so to do, ask for a good deal more

information concerning the intending immigrant than is now called for. This information might well cover medical certificates regarding physical and mental qualifications and even evidence as to pedigree or family-stock value. The American consul would *demand* nothing. He would simply require, as a prerequisite to viséing the passport, that adequate information must be had. If the government of the alien's home country did not cooperate, nothing would be done; the passport would not be given a visa; and the emigrant could not land in America. Thus, automatically, the alien's home government, by refusing to cooperate in the emigration requirements of one of its own citizens to whom it had already given a passport, would reduce its own immigration quota to zero. This would seem a fair proposition on the part of the United States.

In conclusion, the immigration act of 1924 is sound American policy. It expressed the conviction of the American people that "immigration is a long-time investment in family stocks rather than a short-time investment in productive labor." The law is working remarkably smoothly. By giving the different nationalities of immigrants roughly the same proportions of the total quota as these nationalities bear to our total population there is a fair, impartial allotment. In this allotment we recognize the fact that the different nationalities in our country have a natural prejudice in favor of admission of people of their own kind, but we maintain that it is only right for the native-born American to have the same preference in favor of his own stock, and that the only way to treat all alike is to have the proportional representation of all racial groups in our annual immigration, which the act of 1924 assures. This new law, therefore, should be maintained and further strengthened in such respects as experience in its operation shall indicate to be necessary for the fulfillment of its fundamental purposes.

THE FUTURE PROGRESS OF MEDICINE

By Dr. ALEXIS CARREL

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IT appears particularly appropriate, I believe, to speak of the progress of medicine in this hospital where for many years the clinical divisions and the laboratories have worked together for the greatest benefit of the patients and also for the advancement of medical knowledge, that is, for the good of the future patients. We must always realize that the only purpose of medicine is to decrease human suffering by preventing disease or curing it. But this end can not be reached except through a scientific understanding of the functions of the organism when they are modified by pathogenic factors.

To-day, medicine consists of an immense quantity of observations, partly empirical and partly classified according to scientific method. It is a science in the making. While the treatment of certain diseases, for instance, the disturbances of the pancreas and the thyroid gland, is thoroughly scientific, the handling of others, such as mental diseases, is still entirely empirical. It is obvious that the progress of medicine is bound to the development of the sciences concerned with living matter and living organisms. These sciences, which deal with intricate physico-chemical phenomena and meet with immense technical difficulties, have advanced much more slowly than those which concern themselves with non-living matter and occupy a lower rank in the hierarchy of knowledge. Physiology, which was in its infancy when physics and chemistry were widely developed, can not as yet supply to medicine in every part of its field the information necessary for the scientific study of its problems. As the physician must help patients afflicted with all kinds of disease, he can not always remain in the territory which has been scientifically explored. Therefore, his task is very much more difficult than that of the physiologist who can select his problem, reduce it to its simpler terms and solve it by techniques accurately adapted to the subject of the experiments. On the contrary, the physician must wander through the entire field of medicine and often meet with diseases due to unknown causes and developing within an organism of unknown resistance. He is helped by his scientific knowledge as far as it goes. But when he has reached its limit, he has to guess. The great clinician must possess the intuitive power of the man of genius.

The past fifty years have been a period of triumph for medicine because the revelation by Pasteur of the rôle of microorganisms in disease has led to the creation of bacteriology and immunology. These sciences have brought about in a spectacular way the conquest of infectious diseases, a fact of momentous importance to humanity. The death-rate of the population of civilized countries has been decreased by better hygiene and efficient protection against cholera, plague, yellow fever, and also typhoid, tuberculosis, etc. Not only has preventive medicine determined an increase in the quantity of human beings, but it has allowed profound modifications in their mode of living. Men are crowded into large cities and into factories where they work as part of the machines, without danger of great epidemics and without seriously impairing their health. Immense armies, which heretofore would have been rapidly reduced in size by infectious diseases, are kept in the field for years without large spontaneous losses. The admirable work of Gorgas in Panama has opened a new era in the history of mankind. Life in the tropical climates has been rendered possible for the white man, who has thus acquired the power to dominate the entire world. While the ultimate significance of Pasteur's discoveries can not be foreseen, it is certain that medicine, in protecting men from infectious diseases, has already accomplished miraculous progress.

But we may doubt whether this victory has so far brought much happiness to the world. Has it greatly modified the position of the average man as regards disease and death? Probably not. Although the adult individual has much fewer chances of dying from smallpox, cholera, tuberculosis or typhoid fever than fifty years ago, his expectation of reaching the age of seventy-five or eighty has not markedly increased. But he surely has more prospect of being tortured by some form of cancer, afflicted with slow diseases of the kidneys, the circulatory apparatus, the endocrine glands, of becoming insane, suffering from nervous diseases, or of making himself miserable by his lack of judgment and his vices. Modern medicine protects him against infections which kill rapidly, but leaves him exposed to the slower and more cruel diseases and to brain deterioration.

There is no great hope of immediate improvement in this situation, in spite of the remarkable advances which have been made recently in physiology by the discovery of the active principles secreted by endocrine glands, by the building up of the science of nutrition and by a better conception of respiration, of metabolism, of the acid-base equilibrium of the blood, etc. Although great

progress has been accomplished in the treatment of diabetes and of the disturbances of the thyroid gland, it is far from possible to cure these diseases or prevent their occurrence, as we are still absolutely ignorant of their causation. The insufficiency of medicine is more flagrant when it deals with tumors. What are the determining factors of cancer? What is its nature? What are the causes that render the human organism susceptible to malignant tumors? No one to-day can give a scientific answer to these questions. We do not know what brings about arterial hypertension. Our ignorance of the causes of chronic nephritis and of most of the diseases of the circulatory apparatus is practically complete. It is neither possible to cure nor to prevent them. Our lack of knowledge is still greater in the field of the nervous and chiefly of the mental diseases, whose nature remains almost as mysterious as it was during the Middle Ages.

It is clear that the future progress of medicine must consist in finding the nature and causation of some of these diseases and their prevention. Medicine should attempt to lead men to extreme old age without suffering, and also to increase their moral and intellectual value, because the quality of the individuals is far more important than their quantity for the happiness and progress of the community. To expect this from medicine does not appear to be asking the impossible when we consider what has already been accomplished. If our civilization does not crumble, and if scientific research goes on at increased speed, we can reasonably believe that our expectations will be fulfilled. The scientifically organized hospitals, the large medical clinics and their multiple laboratories, the institutes for medical research in this country and in Europe, by merely continuing the investigations in which they are at present engaged, will, without any doubt, immensely advance our knowledge of the nature and mechanism of disease. But fundamental principles have to be discovered; entirely new fields must be opened, and this can be accomplished only by pure science.

Science, when connected with medical research, does not go far enough from the beaten road, and is often handicapped by its attempts to make useful discoveries. On the contrary, pure science has no immediate practical purpose. Its object is merely to find the truth and to understand the universe. It does not attempt to make discoveries which could be applied to industry or medicine, but seeks an accurate conception of the world in which we live and of our relations to it. Pure science classifies the empirical knowledge of nature that we already possess. Beyond the apparent and often puzzling complexity of phenomena, it detects the common

element which underlies their seeming diversity. Then it can draw the generalizations which we call laws and predict and reproduce the phenomena at will. The understanding of nature always has led to its control. Pure science which seeks knowledge in an absolutely disinterested way becomes, almost in spite of itself, the great power of this world. There is no other manner of obtaining a thorough knowledge of nature and of mastering it.

If physiology were studied as a pure science far from hospitals and medical schools, by men possessing the creative imagination and the spirit of the discoverers of the fundamental principles of physics and chemistry, the secrets of the functions of the body that we still lack would be brought to light. These discoveries would indirectly lead the physician to understand the nature of the diseases of the organs whose functions are incompletely known to-day and to prevent them. This institute of pure science, where physiologists, physicists and chemists could devote themselves to the investigation of fundamental problems, would also create the proper conditions for the building up of the science which will occupy the summit of the hierarchy of human knowledge, the science of thinking matter and energy.

The development of this new psychology is our only hope of improving the quality of human beings. But it will be an immense task, because the structure of the central nervous system, as unveiled by Ramon y Cajal, is of infinite complexity. It is probable that the discoveries which will open this field to scientific investigation will be made on the frontier of physiology and physics, and will require the development of entirely new methods by some man of genius. Modern psychology, in spite of its progress, will have the same relation to this supreme science as alchemy to the chemistry of our day. Our knowledge of cerebral physiology is in the embryonic stage. We are still entirely ignorant of the properties of nerve cells, the nature of nervous energy and the significance of telepathic phenomena. No one suspects the manner in which memory, intelligence, courage, judgment and imagination are connected with the brain cells. The possible affinity of certain structures of the brain for some chemical substances secreted by endocrine glands and other tissues has never been studied. While courage may be caused by the effect of the sex glands on the cerebral cells, and may not be due to a property inherent in those cells, creative imagination, judgment and other qualities possibly require for their development the action on the nervous system of substances produced in other parts of the body, or possibly introduced into the organism with the food. The knowledge of the conditions that permit the

evolution of judgment, imagination, kindness or courage in a race, family or individual, or of the conditions that bring about the disappearance of these qualities, would give the human race far more happiness than the complete eradication of plague, cholera and typhus from the earth. At the same time, the discovery of some of the fundamental properties of nerve tissue would enable medicine to prevent many of the nervous and mental diseases.

It is obvious that the functions of the brain must be better understood in order that, without intellectual or moral deterioration, the human race may stand the new conditions of life imposed on the individual by modern civilization. The spiritual progress of man could be greatly promoted by a scientific knowledge of the physicochemical phenomena which take place within the brain cells. Instead of merely increasing the number of human beings, we could increase their quality. The progress of medicine, understood in this manner, would be the most important factor in the development of civilization. As Descartes wrote three hundred years ago, we must ask from medicine the solution of the problems which are vital to the greatness and happiness of the human race—"c'est à la médecine qu'il faut demander la solution des problèmes qui intéressent le plus la grandeur et le bonheur de l'humanité."

THE PHYSICAL BASIS OF DISEASE

By THE RESEARCH WORKER

STANFORD UNIVERSITY

XII. MEDICINE OF THE FUTURE (*Continued*)

9

"SAY! Youse guys'll hav't'git out o' here!" shouted the cameraman. "Got to use this f'r location."

The hormonologist shifted to air-transmission. The henry rose around me, leaving me standing on the lawn with the movie director.

"Moron Educational Filums, Ink," he explained. "Medical dope. 'Charlie and Streptie.' Allegory. We've just learnt how to put this stuff acrost. . . . Now Charlie. Some pep. Ready? Let'er go! . . . Camera!!"

With twirling cane the dearly beloved Charlie shuffled on. Tripped. Regained his balance. Turned sidewise to the camera. Stooped to pick a flower. Thus revealing a string of giant beads attached to his familiar nether garment.

"D'ju get it?" asked the director. "Streptie already attached. Charlie nonchalant. Allegory. Latent period."

A foot-long, glistening stingeree at the end of the string of beads twitched impatiently ("D'ju get it? Streptie's dick-dick. Allegory. Toxin. . . . All right, Charlis. Shove 'er out").

The string of beads, nourished by the life-blood of Charlie's garment, rapidly elongated. Writhed and squirmed. Impatiently darted its deadly dick-dick. Now to Charlie's knee ("D'ju get it? Allegory. Rheumatism"). Now to Charlie's heart ("D'ju get it? Allegory. Endocarditis"). Ever returning to Charlie's mouth ("D'ju get it? Allegory. Commonest portal of entry").

Charlie struggled with the fast encircling beads. Terrified by the flickering dick-dick. Fell fighting to the ground. The deadly dick-dick raised for the knock-out ("All ready, Doug").

The beloved athlete, chicken wings on heels ("D'ju get it? Classical touch"). Obstetrical forceps shield-like over left arm ("D'ju get it? Sex appeal"). Burnished his four-foot hypodermic ("D'ju get it? Science"). Glanced at the safety net. Tail-spinned down the wire to Charlie, now contorting in death agonies. Plunged his giant hypodermic through Charlie's body. Till the needle protruded a foot from Charlie's back. Squirted liquid fire on the deadly stingaree ("D'ju get it? Kills the dick. Allegory. Antitoxin").

The string of beads writhed in agony. Broke in two near Charlie's garment. Registered helplessness. Slunk away to its lair. A dozen loose beads rolled to the ground ("D'ju get it? Allegory. Infection of environment. Close-up later"). One bead only remaining, attached to Charlie's unmentionables ("D'ju get it? Streptie's head. Jaws locked in Charlie's pants. Allegory. Human carrier").

The dearly beloved collie capered on. Unnoticed by Doug, who was trying his durndest to register benevolence. The collie rolled on the grass. Dashed off toward a group of children. Several beads adhering to his hair ("D'ju get it? Allegory. Animal carrier").

Charlie raised eloquent hands to Doug. Doug shook his head. Pointed upward to Mary's perennial curls. Crowned with a glistening 1850-type binocular microscope (" 'Honor not me; but the Spirit of Science, my Guide, my Inspiration.' Hot stuff! Cut!!").

"Nine o'clock to-morrow, folks. Streptie and Steeple-Jack Jim."

And, the henry again under me, I was speeding with the hormonologist toward a distant group of buildings.

10

The henry plunged through a plate glass-window. And I breathed the blended incense of balsam and bull durham, familiar atmosphere of the histological stock room. I looked around. Dark-green walls, mahogany-colored furniture, dull-black table tops, dark brownish-green floors, cream-colored ceiling, ground-glass skylight, windows well above the level of the eye.

"Looks like the specifications for a histological laboratory I once prepared," I said. "Turned down by the university architect."

"Modern cytology," said the eminent histologist in whose research room I was sitting, "dates from the invention of the ultramicroscope. This did for cytology what the compound microscope did for gross anatomy in your day."

"The ultramicroscope," he continued, "was the outcome of the discovery of a method for light amplification. A mechanic in one of the Hollywood studios. Was first applied to night photography. Finally adapted to optical instruments.

"Its first use in cytology was in the study of protozoa. Many details revealed by faint, oblique, multiple illumination, obscured by the intense transverse illumination of your day. Ultraviolet rays were finally adapted for the initial luminant. For routine work we use a magnification of a hundred thousand diameters."

"Our greatest difficulty," he added, "was in preparing the extremely thin tissue sections necessary for these magnifications. This we finally did by ———"

And I found myself back in the henry, still speeding with the hormonologist toward the distant group of buildings.

11

"What happened?" I asked.

"Cigarette hit the windshield," he explained. "Dropped from upper ———"

And I was struggling in the grasp of something I could not identify. With a mighty effort I freed myself. Threw out my hands. Caught hold of the back of the front pew.

"There has arisen in this day," intoned the Rabbi, "a group of skeptics, who would explain away Tamalpias as a natural phenomenon, a blending of mob-psychology and geomutans, even suggesting borings in that Sacred Mount. Who are they, ultramicroscopic worms, to question the instrument through which Omnipotent Bio-Rationality make His revelation!"

"After Tamalpias," continued the curate in whose library I was now sitting, "physical or bodily evolution was the universal teaching of the church. Many ancient manuscripts were eventually brought to light. Among them, the Vatican Manuscript, in archaic Arabic, and the Babylonian Manuscript, in cuneiform. Both give accounts of man's creation antedating the oldest manuscript incorporated in Genesis, by at least two thousand years. In 2135, translations of these two manuscripts were added to the Bible. They are the basis for our present interpretation of Genesis. Here they are, Pregenesis Legends, Babylonian Manuscript, First Scroll:

> 12. IN THE SIXTH DURATION, GOD MATERIALIZED ON EARTH, AND KNEW OHN, FAIREST VIRGIN OF THE SIMIIDAE, AND TO THEM WAS BORN AH-OM.

And here, after describing Ahom's ostracism by the Simiidae:

> 21. AND GOD TOOK COMPASSION ON AHOM, AND LAY WITH MOE, VIRGIN OF AHOM'S CLAN, AND TO THEM WAS BORN AH-OV.

12

"The ultramicroscope must have revolutionized histology," I said to the hormonologist, as I regained my balance in the henry.

"The cell, of course, is no longer regarded as the biological unit of life," he replied. "Our unit is the biophore, or bion. Fixed and wandering intracellular units. Various types. Various struc-

tures. Various functions. Uniting and cooperating to form the cell. About the same way cells are united and coordinated to form the body."

"A remarkable development of intracellular histology since your time," he continued. "And of intracellular physiology. Contractile bions. Conducting bions. Digestive bions. Bion mitosis. Amitosis. Bional conjugation. Bional distribution in the blastoderm. Interbional hormones. Extra-cellular or free bions. Comparative bionology. Why! These terms must be new to you! Bional hyperplasia. Metaplasia. Bional atrophy. Bional regeneration. Bional senility. Bional crises. Differential bion-counts. Bional symbiosis. Bional parasitism. Pathogenic bions. Bion infections. Antibion therapy. Bional ———"

"Yes," I interrupted, I fear somewhat impatiently. "And a thousand years from now some one will kick your bion to pieces. And biology will revolve about an ultra-on."

"Possibly. Probably. But not the histologist. It may come from the chemical laboratory. Chemists are already approaching it. With their self-synthesizing colloids."

"You will be imagining self-propagating pathogenic molecules next," I said.

"Why not?" he replied. "A single foreign self-synthesizing molecule might conceivably cause death."

"Shades of Novy!" I said.

"And then what becomes of your theology!" I added. "Unbroken chain from self-synthesizing molecules to man, the highest self-synthesizing colloid."

"With the development of cytology there has been an intensification of religious belief. Not one fact has been discovered, nor can ever be discovered, contrary to our present religious conceptions. The Unknowable of your time has been multiplied to the ten-thousand-fold Mystery of to-day. The Omnipotent Purpose, that is above all and within all. That breathed life-potentiality into the colloid molecule. That coordinated a thousand molecules to the bion. That harmonized ten thousand bions to the cell. That differentiated, and blended ten million cells to the animal body. That breathed the dawn of Rationality into the bodies of the Simiidae. Herald of the day of human coordination in tribes and nations. And of the ultimate, inevitable world coordination, world-cooperation. Perhaps beyond. Do you wonder that a renowned biologist now sits on the Throne of St. Peter! A great biochemist at Westminster!"

"Children's Ward," he explained, as the henry circled an outlying group of buildings.

13

And I found myself, greatly reduced in size, sitting with other six-year-olds, on the lawn, grouped about the hormonologist, who meanwhile had grown a long Santa Claus beard.

"And did they do what Peter said?" asked Billie on my right.

"No, indeed," answered Santa. "Why! The very next day! When Peter was away. Away up in the clouds. Exercising his Flamingo. They went down Nevergo Lane. Wendy. And John. And Michael. Down the Forbidden Lane. And they came to Peter's sign:

ITCHY-ITCHY GLEN
TresPassgers
Will be ProsTicuted!

"Did that stop them? No, indeed! They went right on. Past Peter's sign. And came to Peter's fence.

" 'It isn't a very strong fence,' said Wendy.

" 'It isn't a very high fence,' said John.

" 'Wigg'y fence,' said Michael.

"Then Wendy saw some flowers. On the other side of the fence. In Itchy-Itchy Glen. Beautiful flowers. And John saw some butterflies. On the other side of the fence. In Itchy-Itchy Glen. Beautiful butterflies. And Michael saw some birds. Beautiful birds. Red. And yellow. And blue. An'———"

"And purple!" interrupted Georgie on my left.

"And green!" added Billie on my right.

"And purple. And green," agreed Santa. "And spotted. Golden spots. And Wendy crawled through the fence. The way big girls always do. And ran to pick the flowers. And John climbed over the fence. The way big boys always do. And ran after the butterflies. And Michael crawled under the fence. The way little boys always do. And ran after the birds.

"Then Wendy began to itch. And John began to itch. And Michael began to itch."

"He! He!" giggled Georgie on my left.

"He! He!" echoed Billie on my right.

"It was no laughing matter," said Santa, very sternly. "These were terrible itches. Terrible. First Wendy itched. Then John itched. Then they all itched together."

"Ugh!" squirmed Georgie on my left.

"Ugh!" wriggled Billie on my right.

"Then Wendy began to scratch. And John began to scratch. And Michael began to scratch. Then they all scratched together. They scratched their arms. They scratched their legs. They scratched their backs. It was worst on their backs. Right in the middle. Where they couldn't quite reach."

"Ugh!" said Georgie on my left.

"Ugh!" echoed Billie on my right.

"Then they rolled on the ground. The way Nana does. When she has itches. First Wendy rolled. Then John rolled. Then Michael rolled. Then they all rolled together.

" 'If Nana were only here,' said Wendy. 'She'd know what to do.'

" 'She always does,' said John. 'She'd know what to do.'

" 'Always does,' said Michael.

"And then they heard Nana's bark. Nana's worried bark. Nana's very worried bark. And Nana came. Bounding over the fence. Into Itchy-Itchy Glen. Nana wasn't afraid of Itchy-Itchy Glen. No, indeed! Nana was magic. She had often chased rabbits in Itchy-Itchy Glen.

"First Nana rubbed against Wendy. And looked up at Wendy. And whined. Then Nana rubbed against John. And looked up at John. And whined. And barked. And whined.

" 'That's her unhappy bark,' said Wendy. 'Her very unhappy bark. She's trying to tell us something.'

" 'If she could only talk,' said John.

" 'Only talk,' said Michael.

"Then Nana ran to a stone. A sharp stone. A very sharp stone. And hit her paw on the stone. Hit it hard. Very hard. And looked at her paw. And whined. And hit her paw again. And shook her head. And whined. And whined. And whined.

" 'That's her discouraged bark,' said Wendy. 'Her very discouraged bark. She's trying to do something. She just can't do it.'

" 'Trying to do some magic,' said John. 'Just can't do it.'

" 'Can't do it,' said Michael.

"Then Nana threw up her head. And howled. Her biggest howl. Her very far howl. And howled. And howled. And howled.

" 'That's her Peter bark,' said Wendy. 'Her very Peter bark.'

" 'She's calling Peter,' said John.

" 'Calling Peter,' said Michael.

"Then Peter came. On his Flamingo. Standing up. Driving with ribbons. And Peter jumped off. Right into Itchy-Itchy Glen. Peter wasn't afraid of Itchy-Itchy Glen. No, indeed! Peter was magic. He had known all along what would happen to the children. If they went to Itchy-Itchy Glen. That was why he had put up his sign. And his fence.

"And Peter knew what to do. Yes, indeed! Peter knew all the magic. First Peter drew his sword. His magic sword. The sword

with which he had fought the Pirates. Then Peter held the sword out. Held the sword toward Nana. The very pricky tip of the sword toward Nana.

"Then Nana barked. Her happy bark. Her very happy bark. And Nana jumped up. And hit her paw on Peter's sword. On the very tip of the sword. On the very pricky tip of the sword. And blood came!"

"Ouch!" said Georgie on my left.

"Ouch!" echoed Billie on my right.

"Then Nana put a drop of her magic blood on Michael. Michael first. Because he was the littlest. And the itches flew away from Michael. Flew up in the air. Forty-'leven billions of them. Just like dust. And the wind blew the itch dust away. Pu-u-ff! Just like that. Away from Michael.

" 'You can't see itches,' said Peter. 'They're so tiny. So very, very tiny. Only when you have a whole bunch of them.'

" 'Just like mama's talcum,' said Wendy.

" 'Taccum,' said Michael.

"Then Nana put a drop of her magic blood on Wendy. Wendy next. Because she was a girl. And Wendy's itches flew up. Just like dust. And blew away. Pu-u-ff!

"Then Nana put a drop of itchy-magic on John. John last. Because he was such a big boy. Almost a man. And away went John's itches. Forty-'leven billion of them. Just like that. Pu-u-ff!

" 'I'll never come to Itchy-Itchy Glen again,' said Wendy. 'Never, never, never again!'

" 'Never, never again!' said John.

" 'Never,' said Michael.

" 'Yes we will,' said Peter. 'We'll build a play-house here. A picnic house. And bring dough-nuts.'

" 'And ice-cream,' said Wendy.

" 'And apples,' said John.

" 'An' punking pie,' said Michael.

" 'And we'll change its name to Nana Glen!' said Peter. 'Itchy-Itchy Glen can't hurt you any more. No, sir-ee! Your magic now. Just like Nana. Nana's blood made you magic.'

" 'Then Wendy kissed Nana. Right on the nose. And John kissed Nana. On the ear. And Michael tried to kiss Nana. But Nana was so happy. She wouldn't hold still. She just jumped up and down. And wagged her tail. Wagged it 'most off. And barked. Her happy bark. Her very happy bark. You see Nana had known all along how to drive the itches away. Nana knew."

"Oh!" said Georgie on my left.

"Oh!" echoed Billie on my right.

"But what I wish to show you," said the hormonologist, as the henry settled to the driveway in front of the administration building, "are some of our diagnostic methods."

14

"Our most valuable diagnostic instrument," said the roentgenologist-in-chief, "is the ford-ray. This has done for non-osseous diagnosis what the X-ray did for bone diagnosis in your day."

"The method is based on the ford-phenomenon," he explained, "rectangular ultraradiation interference. Ford-rays intersected within the body by a perpendication sheet of ford-rays. An optical section is formed, at the plane of intersection. Visible by the light amplifier."

He held out an ocular.

And I saw the optical section of a pulsating heart. An assistant inserted a hypodermic into the patient. Portions of the pulsating heart-wall turned bluish.

"Vital staining," explained the roentgenologist. "Intracellular acidosis of the bundle of His."

Another patient. Optical section of the pyloric region. Hypodermic. Portions of the duodenal endothelism became luminescent. Two flickering stars in a neighboring lymph gland.

"Radium test. Beginning cancer. Two metastatic cells. Ninety-five per cent. probabilities of cure by immediate surgical removal. I suppose you had the beginnings of these tests in your day?"

"Vital staining and the topographical distribution of radium-salts were being studied," I replied. "But nothing had come of it."

Then I entered a darkened operating room. A black-gowned surgeon, ocular to eye. Moving small screws and levers on the end of a trocar, inserted through an uncut abdominal wall. Through a lateral ocular, an optical section of a pus cavity. Surrounding the appendix. Gradually the trocar point entered the cavity. Flowered into a set of tiny instruments. Which slowly moved as the screws and levers turned in the surgeon's hands. The appendix amputated. Sutured. The instruments and appendix fragments disappeared into the trocar.

The pus cavity gradually collapsed. Was dilated. Collapsed again. Finally expanded. The trocar withdrawn.

"Pus aspiration," explained the surgeon. "Followed by Dakin lavage. Final dilation with human antiserum. Plus streptosalvarsan. No necessity for hospitalization."

Another patient. Trocar in blood vessel of neck. Optical section of pulsating heart. Gradually the trocar tip entered the heart chamber. Flowered to a medley of clamps and hooks. Ruptured valve segments brought into opposition. Sutured.

"I wish Graham could see this," I said.

The henry rose to the passenger level and turned toward the emerald foothills of San Francisco Bay.

15

The dean's office, Burlingame Medical College.

"Founded in 1945," he explained, "by far-seeing business men. Union of the Stanford and California medical schools of your day. Now the medical Mecca of Western America. Only rivaled by our sister medical college in Seattle."

"I don't see how you crowd all your new subjects into a four-year medical curriculum," I said.

"Your old subjects, normal anatomy, normal histology, normal biochemistry, normal physiology and elementary bacteriology are required for admission," he answered. "Given in the preparatory college. Where they belong. These courses are also required of all secondary school teachers of biology and physiology. Of course, no student is competent to select medicine as his life-work till he's finished these subjects."

"Overcrowds the college course," I objected.

"Fully a year of your old college curriculum has been moved downward into preparatory schools, and grammar schools. Remember, your educational system was in reality adjusted to the capacity single-plus defectives. These are now shunted as rapidly as possible into trade schools, manual-training high schools, and other non-preparatory finishing schools. Also into non-preparatory junior colleges.

"Our medical curriculum opens with the two basal subjects, pathologic anatomy and histology and pathophysiology. Foundation for the early introduction of clinical work."

"Pathologic physiology!" I exclaimed. "Practically unknown as a teaching subject in my day. Why! I had an acquaintance who spent twenty years, impatiently marking time, waiting for a chance to develop just such a course in our medical schools."

"The pivotal introductory course in our medical curriculum," he said.

"And the age of medical graduations?"

"M.D$_B$., with license as junior physician, about twenty-five. Promotion to M.D$_A$., with license as senior physician, about 30 to 31. Fordate, if won at all, usually 40 to 45."

And I found myself again in the henry with the hormonologist speeding toward the sister medical college in Seattle.

16

"How the Bay Region has grown," I said, as we reached the upper level.

"Following Tamalpias," he replied, "there was a phenomenal increase in real estate values in the old Mills Valley and San Raphael regions. An inflowing deluge of neurotics and hysterics from Southern California. And from the east. Within two generations the region developed into the great Piedmont of to-day. With its three million inhabitants, palatial tourist hotels, magnificent churches and great theological seminaries. With their marvelous biological laboratories. Such a prominent feature of present-day theological education. Strange as it may seem, in place of Piedmont developing into a city of degenerates and incompetents as many predicted, it has become the great literary, artistic and musical center of Western America. As it has the world capital of protestant theology.

"Southern California, of course, suffered from this early piedmontophilia. Within ten years the Los Angeles district lost a quarter of a million people. A period of real estate slumps and business depression. Labor pains of the Los Angeles of to-day. Freed from its former incubus of neurotics, hysteretics and degenerates, the quiet, efficient substratum of keen intelligence in Los Angeles for the first time gained ascendency. Developed Los Angeles into the great intellectual center it is to-day. They now speak of this early period as 'The Years of Purification.'"

"What about research?" I asked.

The hormonologist threw over a lever. The henry swung to the south.

"Los Angeles Research University," he said. "Research Mecca of Western America. Mass production. Ph.D., or equivalent, required for admission. Administration building in Los Angeles. Circled by twenty suburban research institutes."

"And the conditions of work?" I asked

"Five year appointment as research fellow. Salary sufficient for modest luxury. Ph.FD., or equivalent, at the end of that time. Requirement for the fordate, the addition of one new fundamental pioneer fact. Pioneer fact, mind you. After three such facts, he is dedicated an Ace. The Research Acehood, the highest research honor."

"Aces!" I said. "Wonder how many medical Aces we had in my time. Respectable showing of fords. Starling, Smith, Banting, the Dicks. But, Aces?"

The hormonologist disappeared and I found myself standing on a lawn in front of a familiar looking building, its crumbling walls supported and reinforced.

"Old Astronomical Institute," explained a passerby. "Beloved shrine of the Research University. Nucleus around which the university developed."

17

"Of course," continued the curate to whose study I had mysteriously returned, "the Babylonian Legend is not the only legend of simiidaen rationalization. Other legends. Other simiidaean groups. Other parts of the world. But here's something that may interest you. Early segregation of man."

47. AND GOD LED THE SEED OF AHOM APART FROM THE SIMIIDAE, INTO THE VALLEY OF THE DHAN.

"This, also," he said.

69. AND AHOM'S SEED INCREASED A THOUSAND-FOLD IN THE VALLEY.
70. THEN SPAKE GOD TO THE PATRIARCHS:
71. "ALL OTHER VALLEYS GIVE I UNTO YOU, AND ALL HEIGHTS AND PLAINS, AND THE SEAS THEREOF."
72. "AND THE AHOMS WENT FORTH FROM THE VALLEY.

"Numerous other suggestive parallels," he added, turning the pages. "For example, Vatican Legend, First Scroll."

14. FOR SIX GENERATIONS, GOD DWELT AMONG THE AHOMS, AND COUNSELED THEM. ON THE SEVENTH, HE ASCENDED UNTO THE INVISIBLE MOUNTAINS.

"Basis for our present sabbatical system," he commented. "Every seventh year. Beginning with the nuptial sabbatical. All professions. All business. All trades. Except, of course, the pulpit."

"And the pulpit?" I asked.

"We preach only during Sabbatical Years," he said. "Twelve sermons. After six years of preparation and research."

"Daddy! Daddy!" said the five-year-old. "Stop writing! We're almost there."

* * * * * *

"You get off at Burlingame? Yas, suh. Ya-as, Su-uh! Thank y'suh."

"Mama! There's Aunt Linda and Uncle The'dore. See! In Henrioceffus latus."

"A-lo-ha oe, a-lo-ha oe," a diminuendo of student voices, as the train sped onward toward San Francisco.

THE END.

EFFECT OF SUNLIGHT ON GROWTH AND DEVELOPMENT

By Dr. W. T. BOVIE
HARVARD UNIVERSITY

At the University of Maine, Orono, Maine, in the summer of 1924, a clutch of about two hundred and fifty chicks that were about one week old was placed in a greenhouse from which the plants had been removed.

They were divided into six groups, each group placed in a chicken wire cage. The chickens of the first group were allowed to run outside in the open sunlight, although they came into the greenhouse to sleep and eat. The other five groups were confined to the greenhouse throughout the experiment.

The chickens in the second and third groups were exposed to the rays of a quartz mercury vapor lamp for twenty minutes each day. The other chickens were shielded from this lamp.

The chickens in the fourth, fifth and sixth groups received only the sunlight which passed through the glass roof of the greenhouse.

All these chickens received a regular diet of chick grain, dry mash, sour milk and rock grit. Each group was supplied with water and a sand bath. The chickens in the third and fourth groups were given green food, consisting of chopped alfalfa and grass, in addition to their regular diet. The chickens in the sixth group had the regular diet with the addition of a small amount of codliver oil.

The treatment of the different groups is shown schematically in Fig. 1.

The influence of these kinds of treatment upon the growth and development of the chickens was observed and recorded every day.

At the end of the fourth week, the chickens in groups four and five which were exposed only to sunlight which had passed through the glass roof of the greenhouse did not appear to have as good an appetite, were less vigorous in scratching after their food and in their movement about the pens than the chickens of the other groups. The appetite of the chickens in group six which received codliver oil was below that of groups one, two and three. In other words, it was only the chickens in the groups one, two and three, *i.e.*, those receiving direct sunlight or those exposed to the light of the quartz mercury vapor lamp that were normal in every particular.

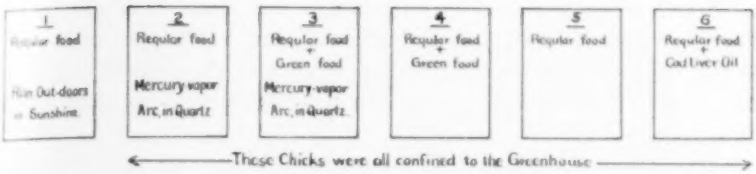

FIG. 1. Diagram showing the arrangement of cages and treatment of chickens in each cage.

All these differences were more marked by the end of the fifth week. At this time the chickens in groups four and five evidenced in marked degree the condition known to poultrymen as "weak legs." The legs appeared too weak for scratching or for support. The chickens remained in a squatting position most of the time, using their wings for additional support while moving about for food. They were unable to stand squarely on their feet and were obliged to assume the characteristic posture peculiar to this disease, with toes crossed and head held low in order to maintain equilibrium. Gradually, as this condition became more fully developed, the nails became long and curled, the bills soft and the plumage ruffled.

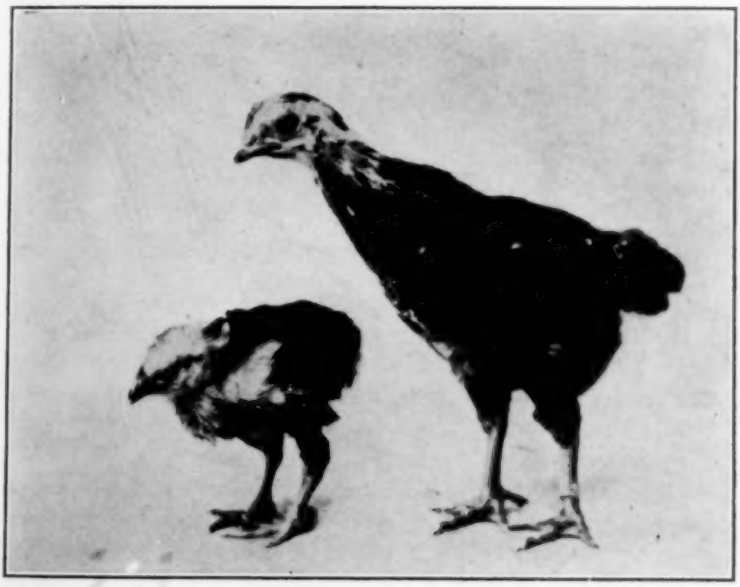

FIG. 2. The small chicken received only sunlight which had passed through the glass. The large chicken had been exposed twenty minutes a day to the light of a quartz mercury lamp. Otherwise it was confined to the glass greenhouse.

Fig. 2 shows very clearly the marked difference in size between the chicks which had received direct sunlight or had been exposed to the light from a quartz mercury lamp and those which had received only the sunlight which had passed through the glass roof of the greenhouse.

The larger chick shown is from group three, the smaller chick from group four. The smaller chick, while not showing the characteristic posture of "leg weakness," was the only one in the group which was able to stand while the photograph was being taken. This condition is also shown in a figure in a paper by Steenbock.

The difference in the rate of growth of the chickens in groups four and five and those in groups one, two and three is shown in the chart, Fig. 3.

The dotted line in this figure is a graph showing the total increase in weight of all the chickens in groups four and five. The continuous line is a graph of the total increase in weight of all the chickens in groups one, two and three. In this chart the number of days' growth is measured along the horizontal axis and the percentage increase in weight is measured vertically. The figure represents only the last thirty days of the experiment.

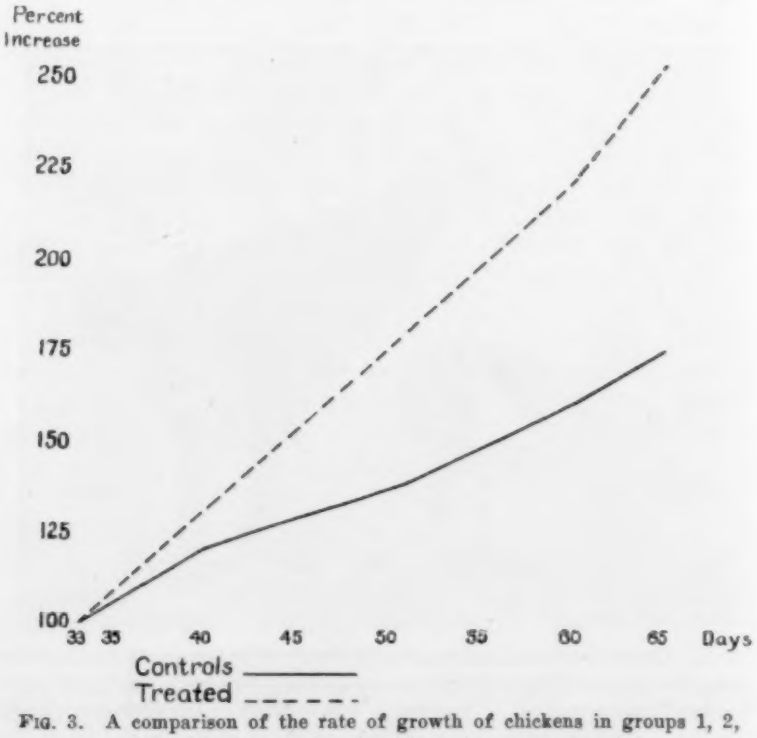

Fig. 3. A comparison of the rate of growth of chickens in groups 1, 2, and 3 with the growth of chickens in groups 4 and 5.

FIG. 4. X-ray photograph of the smaller chicken in Figure 2.

It will be seen that at the end of the sixty-fifth day the total weight of the chickens receiving sunlight only through the greenhouse roof is about one half of the total weight of all the chickens exposed to outdoor sunlight or the light from the quartz mercury vapor lamp.

An X-ray photograph, Fig. 4, of the smaller chicken in Fig. 2 shows a lack of development of the leg bones. The bones are poorly calcified and crooked. Compare with this the strong and straight, well-calcified bones, Fig. 5, in the X-ray photograph of the larger chicken in Fig. 2. The condition shown in Fig. 4 is typical of all the chickens of groups four and five. The condition shown in Fig. 5 is typical of all the chickens in groups two and three. The bones of the chickens in group one, *i.e.*, those permitted to run out of

doors, were not so thoroughly calcified nor quite so far advanced in development as those of groups two and three which were exposed to the rays of the quartz mercury vapor lamp.

The retardation in the development of the bones in the chickens of groups four and five was paralleled in the development of the secondary sex characters. The secondary sex characters (comb, etc.) had not begun to develop in the chickens of these groups at a time when they showed an advanced stage of development of the chickens of groups one, two and three.

The chickens receiving cod-liver oil showed well-developed but small bones. These chickens apparently did not like the taste of cod-liver oil, for their appetite seemed poor, and they showed such a slow growth throughout the first part of the experiment that they were all of a smaller size than the chickens of groups one, two and three.

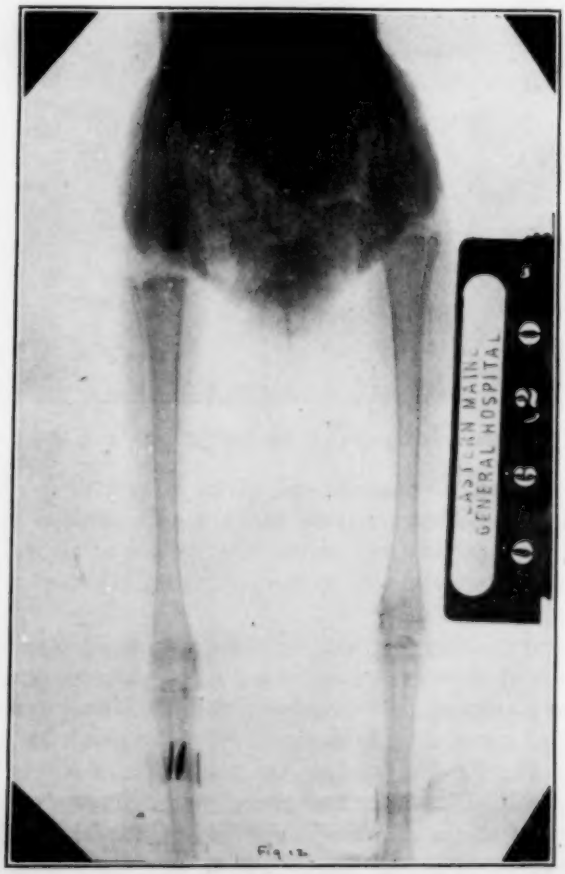

FIG. 5. X-ray photograph of the larger chicken in Figure 2.

While there were fifteen deaths from disease among the chickens in groups four and five, there was only one death among the chickens in groups one, two and three, and it is interesting to note that rats which got into the greenhouse from time to time took chickens only from groups four and five.

Apparently the chickens of groups four and five which were exposed only to sunlight which had passed through the glass roof of the greenhouse have lacked something in the environmental conditions experienced by those receiving either direct sunlight or the light from the quartz mercury vapor lamp. This lack in the environmental condition must be found in the differences in the illumination to which the chickens were exposed, for no differences in diet, excepting in group six, where cod-liver oil was added to the

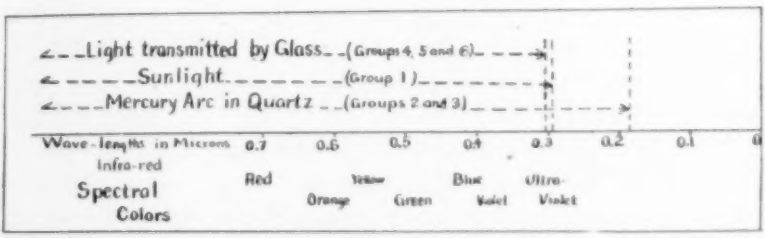

FIG. 6. Spectral colors arranged according to wave length, showing spectral limits of the light received by groups of chickens.

regular diet, produced discernible results. The differences in illumination will be made clear from Fig. 6.

This figure shows an array of the spectral colors arranged according to their wave length, together with the spectral limits of the light received by each group of chickens.

Sunlight contains, besides heat and visible light, ultra-violet light down to wave lengths of about 0.29 microns. Glass transmits some of the heat, all the visible light and the ultra-violet light of sunlight down to wave lengths of approximately 0.31 microns, but does not transmit the small band of ultra-violet of sunlight lying between wave length 0.31 and 0.29. The quartz mercury vapor lamp gives out visible light and ultra-violet light down to wave lengths a little less than 0.2 microns.

It will be seen, therefore, that the chickens, in groups four, five and six, did not receive the ultra-violet of sunlight, having a wave length shorter than 0.31 microns, since this ultra-violet could not pass through glass. The chickens from group one which ran out of doors received in addition to the ultra-violet transmitted by glass the ultra-violet of sunlight contained in this narrow spectral band lying between wave length 0.31 and 0.29 microns.

The chickens in groups two and three received visible light and all the ultra-violet emitted by the quartz mercury vapor lamp, *i.e.*, they were exposed to ultra-violet rays having wave lengths down to approximately 0.2 microns.

Since chickens grow and develop normally in full sunlight and since these experiments show that they do not grow and develop normally in light transmitted by glass it is obvious that the differences in the various groups must be ascribed mainly to this narrow spectral band. This band is so narrow that, by analogy with the visible spectrum, it may be considered a pure spectral color lying in the ultra-violet at the extreme limit of sunlight.

It is not difficult to understand why the antirachitic properties of sunlight are limited to this narrow region of the spectrum. One of the oldest laws of photochemistry (known after the name of the man who first announced it) is Grotthus' law. This law states that only the light which is absorbed can bring about photochemical change. Lambert's absorption law states that the fraction of light which is absorbed is independent of the intensity of the beam which enters the absorbing medium. Lambert's absorption law may be stated mathematically as follows:

$$i = I_0 \varepsilon^{-\mu d}$$

in which i is the intensity of the light after a beam having an intensity I_0 has passed through a layer of the absorbing medium having a thickness d. ε is the base of the natural system of logarithms

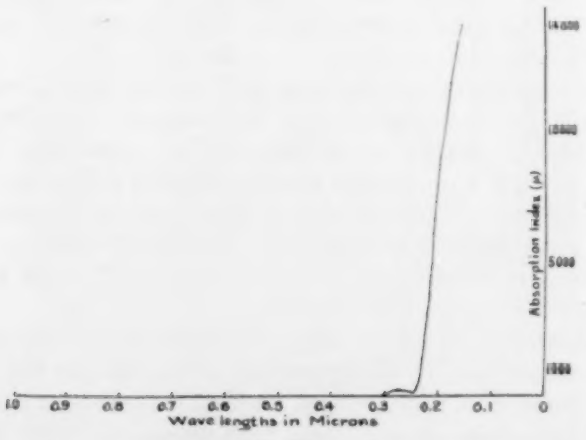

FIG. 7. Absorption spectrum of egg white (probably very similar to protoplasm).

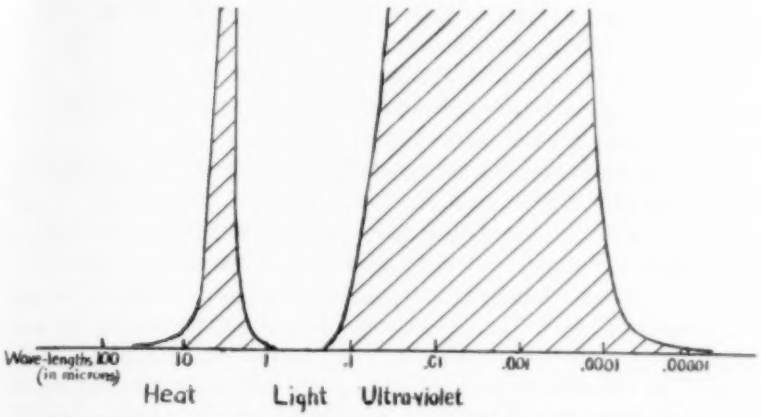

FIG. 8. Regions in the spectrum where protoplasm strongly absorbs.

and μ is the so-called absorption index of the medium under consideration. The value of μ is a function of the wave length of the light, and the absorption becomes greater as the numerical value of μ increases.

The absorption spectrum of a substance depends upon the relation between the value of the absorption index of the substance and the wave length of the light absorbed. The absorption spectrum for egg white its represented graphically in Fig. 7, in which the wave lengths of light are indicated horizontally and the absorption index vertically.

The absorption spectrum of protoplasm probably is not very much different from the absorption spectrum of egg white. It will be noticed that the absorption index of egg white begins to rise rapidly very nearly at the place where sunlight ends.

There are two regions in the solar spectrum where protoplasm especially absorbs; one is in the heat region, and the other in the ultra-violet. This is shown in Fig. 8. (In order to give the figure more convenient dimensions a logarithmic scale is used for the wave lengths. The values of the absorption index are not plotted to scale because we have no experimental data.)

The part of the spectrum having wave lengths greater than 0.8 microns is called the infra-red or heat region of the spectrum. That protoplasm absorbs energy in this region is shown by the fact that we are warmed by the sun's rays. Visible light is only slightly absorbed by unpigmented protoplasm.

We can well understand that sunlight which had passed through a water screen which does not transmit the heat rays of the sun would not warm us. In precisely the same manner glass screens out ultra-violet rays of the kind which are strongly absorbed by protoplasm.

Energy from both parts of the spectrum where protoplasm absorbs strongly is necessary for the normal growth and development of the chickens; and it has been found by experiment that these rays are necessary for the normal growth and development of many other organisms, including man.

That light influences the shape and growth of plants has long been known to the botanist, and is a matter of common knowledge. Any one who has raised plants in a window box knows that the plants must be turned so as to expose all sides successively to the light, if a symmetrically formed plant is to result. This is because the growing tips bend toward the light and the leaves take up positions that expose the greatest amount of leaf surface to the light. Plant physiologists call this bending toward the source of illumination positive phototropism.

The sensitiveness of plants to light is far greater than is commonly supposed. Blaauw found that an oat seedling would bend toward a light of only 0.00017 candle meter but at this light intensity it required an exposure of 43 hours. An exposure of but 0.001 second was required to produce the response at an intensity of 26,520 candle meters. Blaauw conducted experiments using other light intensities and found that not only did the amount of exposure needed decrease as the intensity increased, but that these were related in accordance with a well known law, the so-called "$I \times T$" law of Bunsen and Roscoe. This law was formulated to express the action of light on a photographic plate and states that for a constant amount of blackening (after a standard development) the product of the intensity and the length of exposure is a constant. Blaauw found that this law is true for the oat seedling over the enormous range of intensities indicated above. As the action upon the photographic plate is unquestionably a photochemical effect, Blaauw's results may be taken as very strong evidence that the light produces a photochemical product in the seedling and, further, that the phototropic response only occurs when the amount of this product reaches a certain minimal value.

If one shades various parts of a young oat seedling by small cylinders of tinfoil (which should be supported in such a manner as not to touch the plant) one can demonstrate that it is only the very tip of the young seedling which is sensitive. The bending always occurs a short distance below the tip. We must conclude, therefore, that the effect of the light stimulus is transferred in some manner from the light sensitive tip to the part which bends for the region in which the bending occurs is insensitive to the light.

Since the plant does not possess nerves for the conduction of stimuli many investigations have been conducted in an attempt to

discover the mechanism by which the effect of the light is transferred from the tip to the region which bends. It has been quite conclusively demonstrated that a photochemical product which is water-soluble is responsible for the bending.

It has been shown that the propagation of the stimulus can continue even across a cut surface which separates the region of stimulation from the region of bending. This may be demonstrated if one removes the tip of an oat seedling by a transverse cut and sticks it on exactly in the original position with ten per cent. gelatin. If the tip which has been thus amputated and reset is illuminated from one side, while the remainder of the seedling is kept dark, the non-illuminated part of the seedling will bend after some time toward the source of light. Therefore, a continuity of uninjured cells is not necessary for the conduction of the phototropic stimulus; such conduction can take place even through gelatin across a section of destroyed cells. This fact makes it appear probable that the conduction of the stimulus is effected by diffusion of substances soluble in water even in the uninjured plant.

The extreme sensitiveness of plants to light justifies the belief that only a very small amount of photochemical product is required to initiate the physiological processes which result in the phototropic response.

We do not know whether it is the photochemical product itself which diffuses from the stimulated to the bending region or whether the photoproduct initiates a chain of chemical changes so that there is a sort of physiological amplification of the stimulus. At any rate, a sequence of physiological events occurs through which a modification of plant structure is brought about.

It will clear our notions if we consider for a moment the probable changes which result in the bending plant.

This is not the proper place to introduce a detailed discussion of the mechanism of growth. Suffice it to say that two things are involved. One is an increase in the total amount of substance and the other is a modification of substance into structural elements. This modification into structural elements is called differentiation. It is obvious from a consideration of Lambert's law that the photoproduct will be formed in greater amount on the side that is exposed to the light; hence as transportation of materials in plants occurs most readily in the direction of axial growth the tissues on the side that is exposed to light become differentiated and cease to grow, while those on the other side are still increasing in size.

Light has a profound influence upon the rate of growth of plants. Generally, an increase in illumination retards the rate of growth. Most plants put on the most rapid growth at night, par-

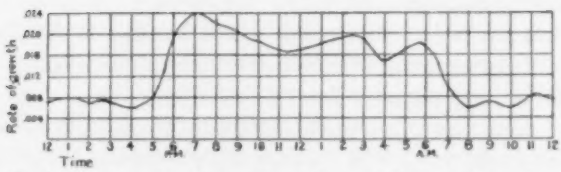

FIG. 9. Variation in rate of growth of four o'clock seedling for one day.

ticularly at eight o'clock in the evening and at two o'clock in the morning.

A number of years ago the author devised a piece of apparatus for measuring and recording the rate of growth of plants. The sensitiveness of the apparatus was such that it would record an increase in length of 1/1000 of an inch. With a rapidly growing seedling the plant will record this increment of growth every fifteen seconds.

Fig. 9 is a record of the growth of the hypocotyl of a four o'clock seedling. Time is measured horizontally and the rate of growth is measured vertically. This curve was made in Cambridge, Massachusetts, during the month of January. It will be observed that the rate of growth began to increase very rapidly at five o'clock when the laboratory began to be dark. There is another rise in the growth curve at about two o'clock in the morning. The two o'clock rise is not as great as that at seven o'clock. This may have been due to the fact that the laboratory was cooler at that time. The curve drops rapidly between three and four o'clock in the morning, when it rises again and then falls as daylight comes. Many other experiments with this apparatus have shown the great sensitiveness of plants to light.

The sharp bend in the curve at four o'clock in the morning is to be correlated with the fact that the day fireman came on duty at this hour and started up the fires in the laboratory heating plant. Curves made on successive days all showed a sharp bend at exactly this time, a rather indirect but effective method of checking on the punctuality of the fireman.

Light influences the rate of growth but does not control it, for the plant continues to grow during the day, and a study of a great many growth curves reveals the fact that growth is a rhythmical process.

It is of course a well-known fact that with the exception of some of the fungi and bacteria, plants can not grow and develop properly in total darkness; the stems are more succulent and there is a deficiency in the amount of mechanical tissue, the green color of chlorophyl-bearing plants does not appear. These conditions are

well illustrated by the ordinary potato sprout which has grown in the cellar.

Plants which have grown in the absence of light are said to be etiolated and in place of chlorophyl a yellow pigment called etiolin is formed. A microscopic examination of the tissues of an etiolated plant shows profound modification in the cell structure. These modifications have been very thoroughly studied by a number of botanists. Sachs, after investigations extending over a period of thirty years, came to the conclusion that a *specific formative material* is necessary for the construction of the various organs of a plant, and, further, that the specific formative material for flowers is formed in the leaves of the plant by the action of sunlight. Sachs believed that this formative material is not identical with the carbohydrates photosynthesized in the leaves, and further, that ultra-violet rays were necessary for its formation. He believed that these ultra-violet rays exerted an important influence upon the growth and development of plants.

MacDougal, in his memoir on the influence of light upon growth, points out that all attempts to establish a direct connection between the action of light on plant tissues and the behavior of these tissues in consequence have so far failed. He says that the basic fact common to all species (except the degenerate chlorophyl-less forms) is that the organs of any plant grown in darkness do not show the same degree of morphological differentiation that is found in corresponding organs of the same age that had been exposed to illumination. The tissues of stems, leaves and floral organs show only limited departures from the embryonic condition when grown in darkness. Comparatively few plants are able to produce a normal abundance of fruit when shielded from the sunlight by glass. MacDougal says further that the physiological effects of exposure to light may become manifest at a time long after the exposure, the effect being carried over even into a succeeding season.

A comparison of the behavior of the normal and etiolated plant offers a demonstration of the fact that growth and differentiation are not only independent but easily separable processes.

While a deficiency in the amount of light results in a delayed or complete failure of tissue differentiation, an exposure to an excess amount of light may result in a premature differentiation as shown by the experiments of Gager.

Gager exposed kernels of corn to the rays from radium. The seeds germinated and grew when the corn was planted, but when the plants had attained a height of a few inches above the surface of the ground growth ceased; an examination of the tissues showed that there had been an excessive amount of differentiation. The

embryonic tissue had been prematurely differentiated into somatic tissues and the plants had died of senility before sexual maturity had been attained. Examples of premature senility of tissues exposed to X-rays are familiar to every physician practicing radiotherapy.

If we interfere with the rate of tissue differentiation in a growing organism the whole process of development may be thrown out of order and the organism may develop into a monster. Hertwig exposed frog's eggs to radium rays and found that the embryos developed abnormally, forming "radium monsters," due apparently to disturbances in the normal sequence of differentiation. Both Gager and Hertwig found irregularities in the nuclear changes which accompany cell division.

Similarly, the failure to develop mechanical tissues in plants grown in the absence of light presents correlated secondary effects upon growth and development of other tissues and organs in the plant, so that a great variety of departures from the normal growth and development are apt to occur.

The stimulating action of light in producing morphological differentiations is not due to any direct action which the rays exert upon a particular tissue, or upon any part of the organ concerned. The stimulative effect of the illumination may be received by one portion of the body and transmitted to another, or impulses may be even communicated to organs not actually formed at the time the stimulating rays were received.

We do not wish to be understood as saying that the exposure to light is the cause of tissue differentiation. As in many other physiological processes it is determined by a great number of conditions. The exposure to light is one of these determining conditions and when the light intensity is reduced below the optimum it may become the limiting factor.

When excessive mechanical strains and stresses are put upon the various parts of a plant by the forces of gravitation, winds, etc., the plant is obliged to meet them by the construction of mechanical tissues. These tissues—the veins in the leaves and the fibro-vascular bundles in the stems—are not only arranged so as to best resist the strains and stresses, but their minute, microscopical structure is such as to give them remarkable mechanical resistance. When a plant is grown in the absence of light these mechanical tissues fail to develop; and while it is true that the differentiation and development of the entire organism is abnormal, a failure in the development of the mechanical tissues is more conspicuous and hence attracts attention. Bleached celery, for example, is, first of all, characterized by being tender. It is lack-

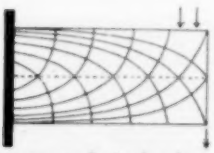

FIG. 10. Distribution of stresses and strains in a beam fastened at one end. (From Thompson's "Growth and Form.")

ing in mechanical tissue, but it is also sweeter than unbleached celery, does not contain as much aromatic oil (celery flavor) and contains an abnormal amount of water. It is more succulent.

The mechanical tissues in animals are also formed in a way to best bear the strains and stresses put upon them. A beam fastened at one end, as shown in Fig. 10, and supporting the load at the outer end, as indicated by the two short arrows at the top of the beam, tends to bend. It is compressed on the lower side and stretched on the upper side. Engineers have determined the direction of these lines of tension and compression. They are illustrated in the figure by the curved lines which cross each other at right angles.

Any engineering structure always contains compression and tension members which in good engineering practice are laid down along the lines of stress and strain.

Fig. 11 shows the stress and strain lines in a crane head and in the head of the femur bone.

Fig. 12 is a photograph of a section of the head of a femur.

The femur consists of a hollow shaft of bone expanded at the ends into articulating heads. It is filled with marrow and contains at the ends a meshwork of bony plates called trabeculae. It will be seen from the figure that these trabeculae are laid down along the stress and strain lines. According to the investigations of Koch, not only are these trabeculae laid down precisely along the stress

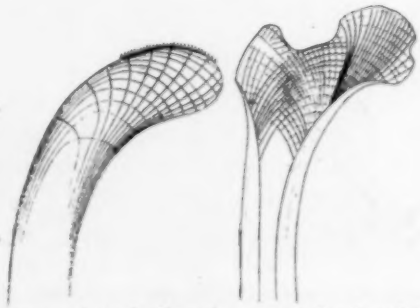

FIG. 11. The stress and strain lines in a crane head and in the head of the femur bone. (From Thompson's "Growth and Form.")

FIG. 12. Photograph of the arrangement of trebiculae in head of femur. (From Thompson's "Growth and Form.")

and strain lines, but the thickness of the trabeculae are proportional to the loads placed upon them. All the bones of our bodies are characterized by this remarkable architecture, an architecture in exact agreement with the practice that has been developed by our best engineers.

Furthermore, the trabeculae seem to be constantly demolished and formed anew, for if the pattern of the stress and strain lines be altered by a change of posture or by such changes as occur when broken bones are set out of line or from the transplantation of bone in bone grafting, it will be found that in a very short time the trabecular meshwork has taken on a new configuration which conforms with the new stress and strain line pattern.

Similarly, in plants, when stress or strain is placed upon a member, as when, for example, fruit is forming, the strength of the supporting members, without any apparent change in configuration of the mechanical supporting parts, have their tensile strength increased so as to support the additional load.

Pfeffer experimented with sunflowers and was able to increase the tensile strength of the sunflower stem from 160 to 300 grams in three days by merely loading the plant with weights, and a few days later the tensile strength had increased to 400 grams, an increase of over 250 per cent.

It is as if an engineer could construct a bridge that would automatically arrange its parts, adding new members or removing them as the case might be, so that the bridge would always have the best sort of configuration to support the new or shifted loads.

The deposition of the bony material in a developing child is one of the processes of tissue differentiation referred to above. In the absence of ultra-violet light this differentiation does not take place properly.

Fig. 13 shows sections of the bones of an animal suffering from rickets. There is a failure to deposit calcium and phosphorus salts in such a manner as to meet the mechanical demands. When a child learns to walk and puts its weight upon the bone the trabecular meshwork that would normally be formed to meet the stresses and strains is not built and they can only be met imperfectly by the curving of the bone, and greenstick fractures easily follow.

Bowlegs may be due to mechanical deficiencies of the bones rather than to putting the weight of the body on them at too early a period. We do not know all the forces which are brought into play in building the mechanical structure of bone, but it appears as in the case of the plant cited above that the weight placed upon it acts as a necessary stimulus to which the organism responds by laying down and strengthening mechanical structures precisely adapted to bear the weight.

It is known that ultra-violet light does not penetrate the organism far enough to reach the bones. This light is absorbed by the surface layers of the tissues upon which it falls and its stimulating action must, therefore, be transferred in some manner to the developing bone.

The same condition is true in plants, for it has been found that illuminating one part of the plant affects the differentiation and development of parts not exposed to the light. Now, in plants there

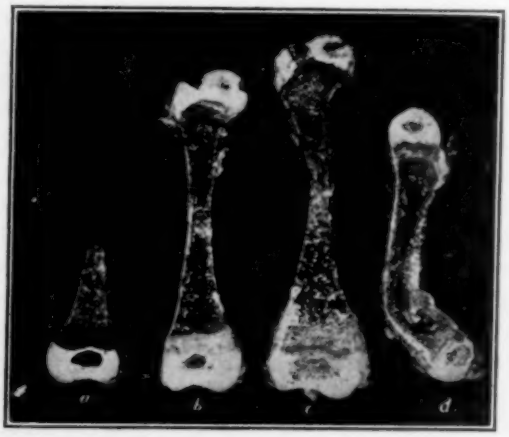

FIG. 13. Photographs of sections of bones from an animal suffering from rickets. (From MacCallum's Pathology.)

is no specialized nervous tissue which serves to transmit stimuli, and it seems reasonable to believe that some photochemical product is formed in both plants and animals. It is this photo-product or "formative material," as Sachs called it, which is necessary to bring about the differentiation.

In plants this material is formed in the tissues exposed to the sunlight, but it appears that in animals the substance stimulating differentiation may either be formed directly in the organism by exposure to ultra-violet light or it may be taken in with the food, for we know that addition of cod-liver oil to the diet has a beneficial action in regulating faulty calcium metabolism. The recent investigations of Hess and Steenbock and others have shown that when certain substances as cotton seed oil, linseed oil, lettuce or dried milk are exposed to the ultra-violet light and then added to the diet, the diet is rendered anti-rachitic; or speaking, more generally, the diet becomes suitable for stimulating normal differentiation.

It may be instructive to draw an analogy between the morphogenic action of light and the action of light upon the photographic plate. When we expose the photographic plate in a camera a latent image is formed in the sensitive film of the plate. This image is invisible to our eyes. The plate appears exactly the same before and after exposure. The latent image is not to be confused with the image which will appear upon the plate when it is developed. By latent image we mean the peculiar photochemical change which has taken place in the silver grains of the plate and which has transformed them into a developable condition. When the plate is subsequently developed, it is found that only those silver grains which have been brought into the developable condition are affected, providing the developer is not too warm.

The sensitiveness of the plate does not depend upon the dispersion of the silver salt in dry gelatin, for the fresh fluid emulsion, before it has flowed upon the plate, needs to be carefully protected from the light.

In the development of a photographic plate the silver grains are reduced while the developer is oxidized. It is conceivable that as chemists we might have been interested rather in the oxidation of the developer than in the reduction of the silver salts; in which case every photographer would have learned that if he wished to oxidize an alkaline solution of hydroquinone or pyrogallic acid (or any other developer) at room temperature, he could add to the developer silver salts dispersed in gelatin, and it would be an essential detail that the gelatin and the silver salts must have been previously exposed to the light. A brief exposure would be sufficient

and the exposure could have been made several months in advance.

Moreover, our photographer would also learn that the emulsions of the silver salts in gelatin varied in their sensitiveness to light. There would be fast or slow emulsions depending upon the method used in "ripening" them, and his familiarity with the process would undoubtedly in time blind him to the mystery of the mechanism and he might cease to wonder why it was necessary that the emulsions be exposed to light in order to oxidize the developer, just as he has now ceased to wonder about the mechanism through which the light makes the photographic plate developable.

Let us now compare the blood to the photographic emulsion. The blood flowing through the baby's arm may be exposed to ultraviolet light of a suitable wave length. Then, after this exposure, when it comes into contact with the embryonic bone tissue, the latent image produced by the light in the blood may be developed by the chemical interactions which occur in connection with the metabolic changes having to do with the differentiation of bone tissues. In a like manner we may consider that the radiated foods of Hess and Steenbock carry a latent image capable of influencing metabolic changes having to do with differentiation of bone tissues.

We do not possess at the present time sufficient information to describe further the nature of these photochemical products or the chemical changes which they induce. We only know that they are necessary for a proper growth and development of the organism.

We may carry our analysis somewhat further, however, by discussing briefly the nature of photochemical change. If every molecule and atom in a chemically reacting mixture were in a suitable condition to take part in a chemical change, every chemical reaction would proceed with the velocity of an explosion. That all chemical reactions are not explosions testifies to the fact that only a certain fraction of the atoms or molecules are in such a condition at any one time that they can take part in the reaction.

When we warm a mixture of chemicals in a beaker in order to increase the rate of reaction more of the chemically passive atoms or molecules are changed into a chemically active condition and the speed of the reaction is a measure of that fraction of the atoms or molecules that have been brought into the activated condition.

If we accept for the time being the electron theory of sub-atomic structure, the atom may be compared to a minute solar system, the electrons taking the place of the planets and revolving about a central nucleus (or sun); and according to the theories of Bohr, Summerfeld and others, when the atom is chemically activated some of the electrons which are revolving in the outer orbits are caused to revolve in orbits which are farther flung from their central nuclei,

so that they revolve in highly eccentric orbits after the manner of comets rather than the more nearly circular orbits as do the planets.

These outer electrons seem to serve in some way in linking the atoms together to form molecules and it is believed that one of the first steps in a chemical union is the throwing off of these valency electrons into farther flung orbits and this has been identified with the chemical activation of the atoms.

The energy required to throw these electrons into far flung orbits may be derived from the heat energy of the reacting mixture, and it is supposed that this energy is acquired by the atoms at a moment of molecular collision.

It is known that when light, particularly ultra-violet light, falls upon some substances they are caused to give off electrons (photo-electric effect). These electrons probably are derived from the atoms of the material upon which the light falls. It is, therefore, easy to understand how an energy like light can hurl electrons into far flung orbits and thus chemically activate the atoms. When atoms are activated by absorbing light energy we refer to the chemical change which ensues as photochemical. If the atoms are chemically activated by heat energy described above we call the change thermochemical.

There are many kinds of atoms and molecules which can be activated by light energy and there are certain kinds of chemical reactions, such as the photosynthesis which occurs in green plants, which can be brought about only by light energy. These reactions are referred to as specific photochemical reactions. The experiments upon the chickens referred to above seem to indicate that the formation of the latent image through which tissue differentiation is brought about is a specific photochemical reaction.

It is well known that silver salts have their sensitiveness greatly increased when they are dispersed in the gelatin of the photographic plate. Moreover, this sensitiveness is further enhanced by the process of "ripening" the emulsion; and during the ripening process certain physical changes occur in the relation between the silver grains and the surrounding gelatin. We may suppose that this physical alteration consists in establishing certain molecular orientations of the silver salt molecules and of the gelatin molecules at the interfaces where the silver grains and the gelatin are in contact. It is perhaps this molecular organization to which we must look for an explanation of the fact that once the silver salt molecules have been brought into the chemically active condition by the exposure of the plate to light they are able to remain in this activated condition until the plate is developed.

Similarly may we not suppose that certain substances in the blood stream and in the tissues of the plants, cottonseed oil, etc., may be chemically activated by ultra-violet light so that a photochemical product is formed that can only be developed when these substances have been brought into the places where they will initiate differentiation?

Physiologists have named substances like those contained in cod-liver oil which catalyze certain physiological processes "vitamines." The above considerations may throw a great deal of light upon the nature of vitamines. They seem to be substances with chemically activated atoms which are capable of hastening the speed of physiological changes so that they proceed at body temperatures and at velocities which would otherwise necessitate very much higher temperatures.

Whatever theories are proposed to explain the reactions, the fact remains that most plants and animals, including man, are as dependent upon the ultra-violet energy of sunlight for normal growth and development as they are upon the heat energy of sunlight. Other physiological functions besides bone development are interfered with when the organism is deprived of this kind of radiation. The body is more susceptible to the inroads of disease. A well-sunned body furnishes a high degree of protection against tuberculosis and the progress of the disease, even after it has been contracted, is often quickly and permanently checked. Window glass has unquestionably accelerated the speed of civilization, but man has paid the price.

RADIO TALKS ON SCIENCE[1]

WHY THE EARTH IS A MAGNET

By Professor W. F. G. SWANN

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If we carry a freely suspended magnetized needle over the surface of the earth, we find that at each place it points in a definite direction characteristic of that place; and, if we draw lines in such a way that they are everywhere parallel to the direction in which the needle points, we shall find that these lines emerge from the earth in a more or less concentrated region near the south pole, and, after spreading out, converge in a more or less concentrated region near the north pole. These lines mark out what are called the earth's lines of magnetic force, and their existence shows that the earth is a magnet. The question of why it is a magnet is one of the most puzzling conundrums which science has to solve. We can not lightly dismiss the matter by saying that the earth probably got magnetized somehow or other at some time or other, and that is the end of the matter; for such permanent magnets as we are familiar with lose their magnetism when heated to temperatures much less than those which we believe to prevail in the earth's interior.

We know that a current of electricity gives rise to magnetic effects; and, as a matter of fact, if we were to wind a lot of insulated wire into a ball, with all the turns going round in the same direction, and then pass an electric current through the wire, the ball would exhibit magnetic properties very similar to that of the earth. Even if we should confine the windings to the surface of a sphere, the earth's magnetism would be roughly duplicated. This effect would not be destroyed by temperature increase so long as we maintained the current; and we are thus led to inquire whether it is possible to attribute the earth's magnetism to currents on its surface or in its interior.

An electric current is nothing but electricity in motion. Now the earth's surface is coated with a charge of electricity of sufficient amount to result in a difference of electrical pressure or

[1] Broadcasted from Station WRC, Washington, December 31, 1924, under the auspices of the Smithsonian Institution and the direction of Dr. Austin H. Clark.

potential between the earth's surface and a point one yard above it one and a half times the difference of electrical pressure between the terminals of our lighting circuits. This charge is in motion as a result of the earth's rotation, and it may be expected to produce a magnetic field. When we submit the matter to calculation, however, the magnetic field comes out one hundred million times too small.

In order to appreciate a few of the possibilities available for accounting for such a phenomenon as the earth's magnetism, it is necessary to remind you of a few of the things which the scientific investigations of the last thirty years have taught us regarding the structure of matter. We believe that structure to be entirely electrical, and that, in its ultimate make-up, only two fundamental kinds of brick are to be found. These are the electron and the proton. The former is the ultimate unit of negative electricity. Its size is so small that if we should magnify a drop of water to the size of the earth, the electron would, on the same scale of magnification, attain a size only just visible under our most powerful microscope. Its mass is about the one thousandth of the one millionth of the one millionth of the one millionth of the one millionth of the mass of a collar stud. The proton has a mass about 2,000 times that of the electron, but its diameter is about 2,000 times smaller than the diameter of the electron, so that if the proton should be magnified to the size of a pin's head, that pin's head would, on the same scale of magnification, attain a diameter equal to the diameter of the earth's orbit around the sun.

The atoms of which matter is composed are themselves built up out of protons and electrons, and the general structure comprises two parts, a central nucleus composed of protons and electrons in close proximity, with electrons revolving in orbits about that nucleus, just as planets revolve around the sun. The hydrogen atom, the simplest of the atoms, has as its nucleus one proton, and around this, at a distance of about the one two hundred and fifty millionth part of an inch, there revolves an electron. To magnify the picture to sizes more commensurable with those to which we are accustomed we may say that if we reduce the sun to a diameter of four miles, and leave the earth at its present distance and with its present size, the picture presented would simulate the hydrogen atom, with the sun as the nucleus and the earth as the electron.

The atoms of heavier substances like iron have many protons and electrons in their nuclei, and many electrons revolving around them. In the case of solids, moreover, particularly those solids which are good conductors of electricity, we believe that many of

the electrons are able to come out of the atoms and wander about more or less freely between them.

Now a cubic inch of a solid such as the earth contains a very large number of protons and electrons, a very large amount of positive and negative electricity—so much, in fact, that if we could separate out all the positive electricity and concentrate it at one point, and all the negative electricity and concentrate it at another point one inch away, the two would attract each other with a force of 36 hundred million million million tons. The neutrality of these two enormous amounts of opposite electricity is like the neutrality of two huge armies which are so interlocked that they have no attention for anybody else. If one of them should weaken in strength, numbers or any factor which affects its power, even to a slight extent, the other could afford to let loose forces to very drastic ends. So it is with the very large amounts of opposite electricities in the earth. If one of them could operate alone, the current produced by its rotation would give a magnetic field five million million million times that of the earth. If the two electricities were spread over spheres of slightly different size they would not quite compensate, and a little magnetic effect would be left over. It would only be necessary for the two spheres, each of about the size of the earth, to differ in diameter by about five hundred thousandths of the millionth part of an inch in order to leave a residual sufficient to provide for the earth's magnetism. When we submit the matter to calculation, however, we find that the forces interlocking the two kinds of electricity are such as to prevent even such a slight separation as this unless we invoke for that separation agencies of such enormous power that we know of no cause which could be responsible for them.

The centrifugal action of the earth's rotation on the free electrons within it would tend to make these electrons fly to the outside and would so increase their efficiency in producing the magnetic effects which we observe, but the effect is a hundred thousand million million million times too small.

The weight of the electrons would tend to cause them to congregate towards the center of the earth, an influence which would be resisted by their mutual repulsions as they came closer together. However, here again the lack of complete compensation of the magnetic fields produced by the positive and negative electricity in the earth results in a magnetic field only the one thousandth of the one millionth of the one millionth of the one millionth of the earth's magnetic field.

The great temperature of the earth's interior will cause the volume of the electrons in the hot parts to swell out, just as a gas

swells out when heated; and here again we have an agency tending to destroy the complete balance of the positive and negative electricity with the result that a magnetic field should be produced. When we submit the matter to calculation, however, we find that we can only account in this way for a magnetic field the one hundred thousandth of the millionth of the millionth of the earth's magnetic field.

These instances serve to illustrate the practical hopelessness of any attempt to explain the earth's magnetism as a result of redistribution of the charges within it brought about by such agencies as we have knowledge of. There are, however, ways of obtaining currents of electricity other than by the rotation of charges which have been more or less separated from each other. Thus, if the opposite charges are completely superposed, but the charge of one sign moves with a velocity slightly different from that of the charge of the opposite sign, we shall get a current. As a matter of fact, nearly all the currents used in practice are produced by the relative motion of completely superposed distributions of electricity. If there were any way in which we could see reason why the negative electricity in the earth should move a little faster in its rotation than the positive, faster to the extent of only one part in seventy thousand million million of the total velocity, we could account for a state of magnetization comparable with that which we find in the case of the earth. Here again, however, nature provides us with no obvious mechanism to account for the desired state of affairs.

I have referred to the fact that an atom of matter is to be thought of as a central nucleus with electrons revolving around it, just as planets revolve around the sun. Now these revolving electrons are the equivalent of a current of electricity; and, in cases where the effects do not mutually cancel in the same atom, they endow the atom with the properties of a magnet. We believe, for example, that the atom of iron is a little magnet, and that it derives its properties in some such way as this. However, the rotation of the electrons in the atom endows it with another property, the power to act like a gyroscope or fly-wheel. If you mount a fly-wheel on a frame and try to make the frame rotate about an axis which is not parallel to the axis of rotation of the fly-wheel, you will find that the fly-wheel brings into play forces which cause it to exhibit a strong desire to turn its axis parallel to the axis about which the frame is rotating. The experiment may be tried with an old bicycle wheel set into rapid rotation. If you incline the axis of the wheel to the vertical, and then run around in a circle, you will feel the forces tending to make the wheel stand

with its axis upright, and the behavior of a bicycle wheel of this kind affords an interesting experience to any one who has never before become familiar with the action of a gyroscope.

Now, as I have said, the atoms act like gyroscopes on account of the revolutions of the electrons within them, and atoms of this kind in our earth will tend to turn so that their axes are parallel to the earth's axis of rotation. If they could all turn this way, the cooperation of their magnetic effects, now all in the same direction, would give rise to a very large magnetic influence of the earth. However, we know that, at all times, the atoms experience an irregular motion as a result of jostling against one another. It is in fact this motion which we recognize in the phenomena associated with heat. The jostling motion tends to annul the gyroscopic motion of which I have spoken, and it succeeds to the extent of reducing the resulting magnetic effect to an amount about ten thousand million times too small to account for the earth's magnetism, even in the most favorable case.

You will doubtless think that, since this talk is entitled "Why the earth is a magnet," I should have spent less time in explaining why it should not be one. As a matter of fact we can not say that we know with any certainty why the earth is a magnet. Before branching out into speculation, however, it is desirable to examine carefully all the possibilities which a rational survey of the situation would suggest. Such a survey seems to lend considerable evidence for the belief that we may have to seek the solution of the earth's magnetism in a slight departure from those fundamental laws of electricity with which we have been familiar in the past. The fact that either the positive or negative electricity contained in the earth would, if rotating alone, with the earth's angular velocity give rise to a magnetic field five million million million times that of the earth suggests that a very slight modification of the laws for positive and negative electricity may provide a key to the situation, for then the complete compensation between the two would be destroyed. Now it is possible to make such a modification in a consistent manner. The details are far too complicated for an exposition in which one can reach his audience only through the voice, and all that I can say is this: One of the characteristic features of the classical viewpoint is that, in the case of a continuous current flowing in a circle, the magnetic effects depend only upon the amount of the electricity and upon its velocity. However, the electricity has other characteristics of motion besides velocity. It has acceleration, for its velocity is changing, and it has rate of change of acceleration, for the direction of the acceleration is changing, and so on. The modification of which I speak

invokes these to a very small extent in the case of the positive electricity, while the ordinary views prevail in the case of the negative electricity. The result is a lack of complete annulment when the positive and negative rotate together. I may add that certain other features evolve at the same time. For the modification of the laws results in the conclusion that, as a result of the rotation, the positive electricity should suffer a slow death, so that there would be a continual accumulation of unbalanced negative electricity. Now this is just what is wanted to account for one of the most puzzling problems of atmospheric electricity, the fact that a current of negative electricity is continually streaming away from earth into space, and yet the earth, like the widow's cruse of oil, does not suffer apparent diminution in its net amount. The rate of death of the positive electricity is very small, so small in fact that it would take a hundred million million million years for one half of one per cent. of the positive electricity in the earth to disappear. I fear, therefore, that it will not be in your time or in mine that we shall find direct evidence of that death of the substance of our earth.

TREE RINGS AND CLIMATE

By Professor A. E. DOUGLASS

UNIVERSITY OF ARIZONA

If trees could talk, they would complain bitterly of snowy weather like this, for the cold stops their growth and offers serious chances of injury. But ages of experience have shwon them how to protect themselves by many adaptations, of which one is a change in the character of the growing wood. This altered effect in the trunk appears in the form of annual rings, which thus are really "scars" of the yearly ordeal of cold through which northerly vegetation goes.

Now a scar tells something of its own story, and we might expect the rings to tell us something of the various experiences of the tree. And so they do, and each ring becomes an annual report, not necessarily of the winter, when growth is stopped, but rather of the spring and summer when growth is most rapid. If one growing season differs from another, the difference is highly likely to show in the rings. And in the successive rings of a tree we get its life story. In the east that story depends on many conditions, such as too much other vegetation, competing for every inch of ground, too much water in the soil, and especially such terrible pests

as the gipsy moth in eastern Massachusetts (I have seen the effect on the shores of Buzzard's Bay) and the chestnut blight; and a tree story here might tell chiefly of such experiences and very little directly of the weather. But conditions in the great pine forest of Northern Arizona are so different that the easterner can scarcely realize them. There the trees are far apart with little or no undergrowth between them: they are miles from any water courses and the ground is dry much of the year. The story in the trees is largely climatic and deals with rainfall and snowfall or, as the botanists say, "moisture is the controlling factor."

This Arizona tree is the yellow pine, much used for lumber. The altitude above the sea, of 5,000 to 9,000 feet, is high enough to make the summer climate lovely and the winter climate cold and bracing, with quantities of snow. So the rings are well marked and very reliable and this tree has proved wonderfully adaptable to this study. Many interesting facts have come out. In the first place, similar sequences of rings are found over very large areas. What that means is this. A heavy winter snowfall in Flagstaff which supplies abundant moisture for the trees there extends over hundreds of miles and supplies abundant moisture in northwestern New Mexico, 225 miles away, or over in the Charleston Mountains near Las Vegas, Nevada, an equal distance west. A dry year in Flagstaff is dry in the other places also. Even at much greater distances the resemblances are enough to enable us to carry dates across. For instance, the yellow pine ring for 1851 is small all the way from Santa Fe, New Mexico, to Fresno, California, a distance of eight hundred miles with nearly four hundred miles difference in latitude. Now this is evidence of a climatic similarity across those great distances and can be used in the study of climatic districts, but I have used it under the auspices of the National Geographic Society in actually determining the date of cutting of certain Spanish beams used in kivas of the Pueblo Indians. It was wonderfully fascinating to make a cutting from an ancient beam in the abandoned part of the village of Oraibi in northern Arizona and find rings that perfectly matched the Flagstaff tree growth and then be able to say that the tree was cut in a certain year a little less than three centuries ago. Fortunately, this society is interested in further research along this line in connection with their excavations at Chaco Canyon under the direction of Mr. Judd.

Another very interesting bit of information has come from these Arizona trees. Since they tell wet and dry years, they can be and are used for the study of drouth. At first I merely compared the trees' growth in given years with statements of famine and flood in the history of Arizona and New Mexico. Then when these seemed to agree I made a more formal search for drouths. This was really

done because various persons interested in reclamation wanted to know how big the reservoirs would have to be in order to take care of dry years. I found easily enough the historic drouths of 1682–6, 1748, 1777–82, 1822, 1879–87 and 1902–4. But I found also a very severe drouth from 1729 to 1741 and a still worse one from 1573 to 1587. Both of these were felt from New Mexico to California. So the trees give us much historical information of value in engineering.

And this brings us to the age of these Arizona trees. My collection includes ten trees whose age is five hundred years and one whose life covers six hundred and forty years. These figures are probably very accurate, for they are reached not merely by a process of ring counting but by a minute comparison between hundreds of trees so that every possible error is avoided. In fact, no tree record is used unless it has been compared with others and found to show minute similarities that can be recognized. The early counting of rings in these yellow pines was later found to have four per cent. of error, due mostly to missing rings which in the outer parts of very old trees may be readily overlooked. These were all discovered by comparing many trees together.

Of course, I have collected sections or cuttings or samples of rings of other trees than the Arizona pines. Of these others the most interesting are the big trees or *Sequoia gigantea* of California which grow at elevations of five to seven thousand feet in the high mountains east of the great central California Valley. My chief collection comes from the King's River country east of Fresno near the General Grant National Park, where much lumbering has been done. I do not like to think of those giant trees being cut down and I hope that no more will be sacrificed, but yet it is the stumps which have supplied most of my material. I have in all thirty-three cuttings from there, two from the grove east of Porterville and this summer five small cuttings from fallen trees in the Calaveras Grove which I obtained by kindness of Mr. Whitesides, who owns the grove. Of course many interesting facts have come out from this study of the sequoias. The rings do not tell quite so accurate a climatic story as the yellow pines and yet on the high and dry ridges it is still a story of moisture. The basins between the ridges have streams flowing through in the summer and the rings are larger and more uniform. There is a great dependence of the growth on the proximity of running water. And thereon lies the blame for overestimating age in many cases. The oldest tree so far found, whose age is absolutely reliable, shows a ring which grew in 1306 B. C. That makes an age which to-day would be over 3,230 years. That particular stump was found by Ellsworth Huntington more than ten years ago.

Now that age was determined by an inter-comparison of some twenty-three trees, mostly over 2,000 years old. That comparison took me a year and after it was done there was a possible error of one year, namely, a possible extra ring which occasionally seemed to show for the year 1580 A. D. So an extra trip was made to the King's River region to settle this question and twelve new specimens were secured which verified this supposed ring as real. So it is probable that the date of the beginning of this tree is correct. I have looked at thousands of stumps and failed to find anything older. In the trip referred to, I looked at some living trees, measuring their size and testing the size of the rings near the outside in sundry burnt places and judging the effect of relation to water, but did not get anything of longer life than this. The General Grant tree may be 2,500 years old. I have not yet seen the General Sherman in the Sequoia National Park. A stump of 25 to 30 feet near the General Grant Park had grown near a stream and had only 1,500 rings. A similar stump in a drier place in the Porterville region has 3,100. It is the stump from which a specimen was taken for the Centennial in 1876. The oldest tree, as mentioned, grew near the Converse Hoist close to the General Grant Park and was only about 22 feet in diameter. The famous Dance Hall stump in Calaveras Grove, mentioned by Mark Twain, was a quick-growing tree and probably did not have more than 1,500 or 1,800 rings. On the whole, the Calaveras trees are not so old as those farther south. The point that proved important at Calaveras was that the rings could be identified with those in the other big tree groves. So that now we know that all the big trees give a somewhat similar story.

Now what is all this for? It is to get all the information we can about climatic conditions in past time and in distant places. Our yellow pines give us the drouth and rain history of five or six hundred years in Arizona: the sequoias give us data for more than three thousand years. We can therefore make extensive historical studies and especially we have a chance to test climatic cycles or recurring climatic conditions by the aid of data which go back far beyond the use of instruments for measuring rainfall or temperature, even though these tree records are not quite so accurate. Yet they are accurate enough to have a very real value. This I became sure of two or three years ago. I had studied the eleven year solar or sunspot cycle in the Arizona trees and found it there for most of the time, but from about 1650 to 1730 or 1740 it disappeared, so that I was in some doubt whether the trees could be reliable. However, I published the facts as I had found them and said that about 1700 the solar cycle flattened out. Three years later,

a letter from the noted English astronomer, E. W. Maunder, of the Greenwich Observatory, said that he had been studying old sunspot observations and that betwen 1645 and 1715 there were none or very few seen and that the trees ought to show this if they were giving real solar history. The dates agreed so well with my time when the trees failed to show the solar cycle that confidence in the tree ring history seemed well placed, and it appeared pretty certain that the solar cycle has been operating since 1400. The sequoias are extending that history farther back. We have constructed an instrument for studying cycles, for the mathematical processes are very long, and we have some 500 curves prepared for analysis. We are beginning to see certain cycles which rather dominate things, and it seems as if they were related to solar changes, but it is perhaps a little early to speak of them with precision.

Finally the study of tree rings will give us further knowledge of the distribution of conditions about this world of ours. Of course trees do not have the same climate everywhere and so show different responses, but making allowance for that we get some knowledge. Thus the pine trees about the Baltic Sea give a very accurate history of the sunspot cycle for the last century. When this study is extended to all parts of the world we shall have certain general information which would be too expensive to get in any other way. In carrying out that idea the Carnegie Institution has assisted in collections from a large number of locations in the southwest.

So Good Night. I thank you.

GROWTH IN TREES

By Dr. D. T. MacDOUGAL

CARNEGIE INSTITUTION OF WASHINGTON

ALMOST every one has seen young leaves on a tree unfold and lengthen in the spring. Branches shoot out in the same way and seeds sprout or "come up" out of the ground. The mechanical forces involved in the growth of plants, like scores of the commonest happenings all about us in nature, are not widely or well understood.

Many will be surprised to hear that growth is due to the action of mechanical forces at all, but this is clear when one sees rocks split apart by roots which enter small crevices when they are tiny rootlets and then, as they grow larger, separate or lift masses of stone weighing hundreds of pounds. Mushrooms with tender,

fragile stalks come up beneath pavements and lift the bricks out of the pattern.

The roots of one kind of plant are driven through the ground by a pressure which may be as great as five or six hundred pounds to the square inch. Large roots and underground stems of one plant actually may be pierced by the small roots of another plant which chance to grow in the direction where the large root is in the way.

Most striking of all is the growth of a tree. Giant columns of trunks and great branches are thrown up two or three hundred feet in the air. It is true that this great weight is not all lifted at once, but it must all be lifted some time and somehow. The machinery by which this is done is simple enough in plan but quite complicated in operation. The power for operating the machine is derived from sunlight. A steam engine converts water into steam by using the heat from fuel. Similarly, the leaf of a plant converts water and carbon dioxide gas which it gets from the air into sugar. This sugar is actually burned in the plant to obtain power, or sometimes it may be converted directly into wood.

Underneath the bark of all trees is a very thin, silvery layer of living, growing cells, the cambium. These cells use up the sugar made by the leaves to build new layers of wood on the outside of those already formed. These new layers are sometimes not so thick as a dime. In other cases they may be a half inch thick. This new wood is added to the trunk of the tree every year. At the same time other living cells in the buds use sugar in building new cells on the ends of branches, by which the branches are made longer. A branch of the famous Monterey pine tree may elongate as much as six or ten feet a year. If a growing morning-glory vine is measured every day, it will be found to add several inches to its length in twenty-four hours.

These facts about the growth of plants are one part of my story. The other important part is that of the movement of the sap in trees. Water from the ground must be carried up to the leaves of all parts of the top of the tree. At the same time the sugar formed in the leaves must be carried down the entire length of the tree trunk, even to the extreme tips of the tiniest rootlets which may be many feet away from the base of the tree. In some cases this sugar which the roots use for food must be carried downward as much as four hundred feet.

The pipes through which the liquids move upward and downward inside the plant are just beneath the living, growing layer of cells. Some of these pipes are like long tubes. Others are like

organ pipes welded together with the ends overlapping, the connection between each two such pipes being through a thin membrane or strainer with minute holes in it like a sieve. The sap is pulled up through this pipe system by the power of the sun, but that is an entirely separate story, which I may tell you some day when I learn about it by experiments on some of the famous Big Trees or redwood trees of California.

Thick liquids like molasses flow most readily when they are warm. It is true, too, that coal burns best in a hot fire. Just so, a tree grows fastest when it is warm, but of course it must not be too warm. When the physician wishes to know whether the body of his patient has become too warm or too cold, he uses a small thermometer which is placed in the mouth with its bulb underneath the patient's tongue. When we wish to obtain similar knowledge about the temperature of a tree, we cut a small hole in the skin or bark of the tree and place the bulb of a small thermometer in contact with the soft growing cells underneath the bark. If the air temperature is then measured by a second thermometer, suspended from a branch nearby and shaded from the sun, some very interesting comparisons can be made.

It will soon be evident to any one who performs this simple experiment that the tree never gets quite as cold as the air. On the other hand, it never becomes quite as hot. This protection of the living cells from extreme heat and cold is one of the uses of the bark to the tree. The second fact that will be seen by one using two thermometers in the manner I have described is that the tree is not coolest at the time when the air is coldest, but an hour or two later. Similarly, while the hottest part of the day, as we feel it and as the thermometer shows it, is usually shortly after noon; the tree does not reach its highest temperature until later, perhaps as late as three or four o'clock in the afternoon.

Nearly all kinds of our common trees cease to grow when the temperature under the bark falls below forty-five degrees, which is still twelve or thirteen degrees above freezing. Not many kinds of trees live in places where their cells become hot enough to stop growth. I have not found any kind of a tree or a shrub which can grow after its cells reach a temperature of one hundred and twenty-five degrees. Only certain special kinds of plants which live in hot deserts are able to remain active when it is as hot as this. Trees like the pines, the beech, the maple and the oak do not grow when their trunks become warmer than our bodies, that is, warmer than about one hundred degrees.

The living cells of the tree are not actually killed by these high temperatures, for I have found that the stems of a cactus plant in

Arizona may become as warm as one hundred and thirty-six degrees and still live. The tree likewise can endure very low temperatures without damage. But, although life persists, growth will not continue when the temperature is either too high or too low. The growing layer on the outside of a tree is most active in creating new living cells, and hence most wood is formed, in the moderate favorable temperatures.

The intense sunlight and heat of a warm day make much sugar in the leaves and this also speeds up growth, but other effects are produced which make exact measurement difficult. I have designed a special instrument called a *dendrograph* for making such measurements. This instrument is fastened to the trunk of the tree to be measured and has a pen which traces each tiniest change in the thickness of the trunk on a sheet of paper.

Having thus furnished the tree with a pen, it faithfully writes its own diary, if only we keep it supplied with ink and paper.

The first thing which arrests our attention in these self-written stories of the trees is the fact that the trunk, especially the trunk of a pine tree, begins to shrink a little in the morning and continues to do so until afternoon. This apparent shrinkage, even during the time of the day when new living cells are being formed in the growing layer inside the trunk, is due to the fact that water is being sucked out of the tree at its top faster than it comes in at the roots. By sunset the air cools off. The evaporation of water from the leaves is lessened and the water pipes inside the tree trunk swell up. The tree is then larger than it was the night before, for some new wood has been formed during the day.

So, when the tree records its daily behavior by tis diary written on the *dendrograph*, its story for each week is a wavy line on a strip of paper a foot long. To the student of trees this line tells as much as if the tree had used hundreds of words. The expert in tree handwriting sees at a glance what the tree did every hour in the week and also knows why the tree did each particular thing.

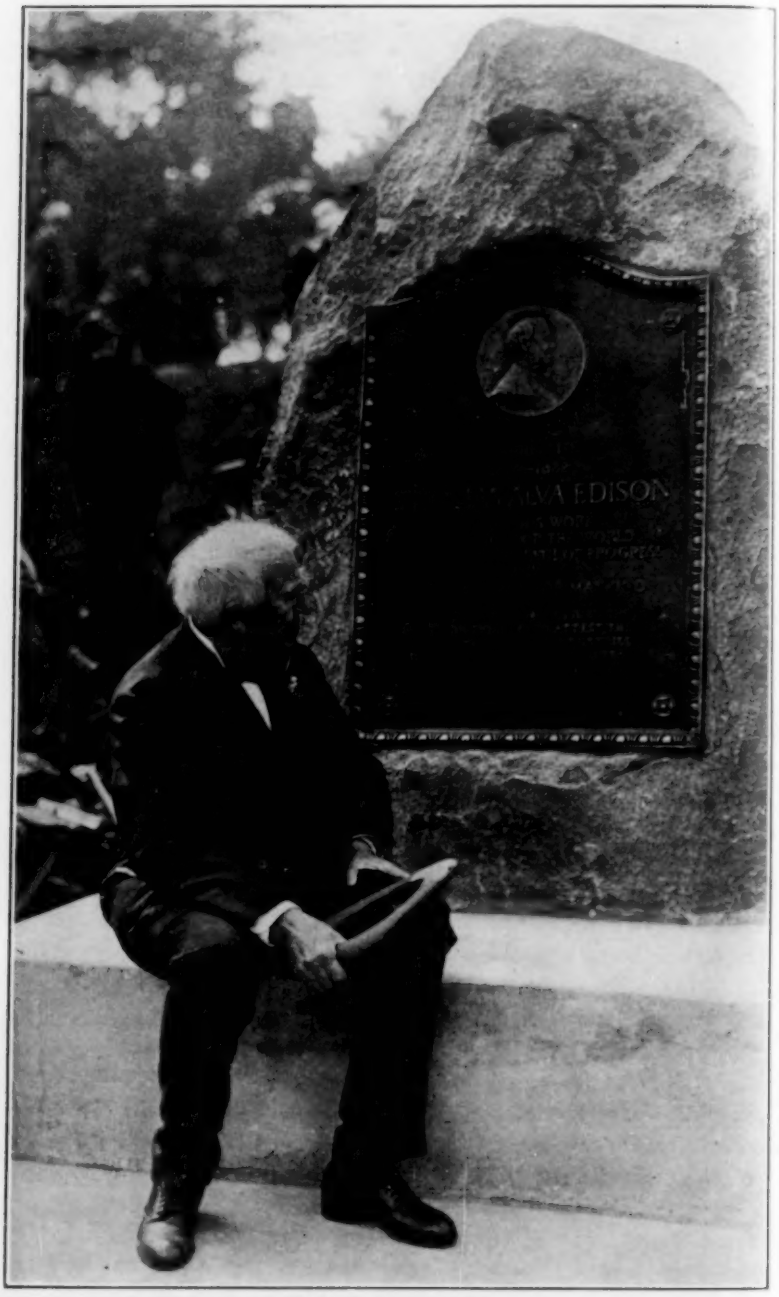
It may be seen, for example, that it was warm and cloudy on Monday, in consequence of which the tree grew rapidly and strongly; that it rained on Tuesday; that the hot sun on Wednesday caused a very noticeable shrinkage of the trunk on Thursday, which became even greater on Friday when a gentle breeze increased the evaporation of water from the leaves. Or, if such a misfortune befall as that the young leaves of the tree were eaten by animals or were cut off by beetles, this tragedy would be told in unmistakable terms on the tree diary of the *dendrograph*.

Two persons do not tell the story of an event in the same words, and the handwriting of one person is never exactly like that of any

other person. This is true of trees, also. The handwriting of the oak can be distinguished readily from that of the ash, while no pine tree could successfully forge the signatures of a walnut or a maple or a beech.

I have accumulated diaries of several kinds of trees growing in various places in the United States from the Atlantic to the Pacific Oceans. The total of the periods covered by these diaries is now about one hundred and twenty years. If these records were thrown together haphazard in a pile, they could be sorted out again easily by the mere character of the individual writing.

Many things can be learned from these tree diaries. We have not yet studied the growth of trees in the tropics where it is always warm and where new wood may be formed on trees almost every day in the year, but in eastern America the season of growth may not begin until May or June. For most kinds of trees in this region the growth season ends in July or August, but these dates differ somewhat for different kinds of trees. Most trees carry out all their annual growth within sixty to one hundred days, which is about the length of time required for the maturing of the ordinary field crops, like wheat and rye.



THOMAS ALVA EDISON

and the tablet erected in his honor by the Edison Pioneers at Menlo Park, N. J., where Mr. Edison lived and had his laboratory from 1876 to 1882 at the time that the incandescent lamp was invented by him.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

THE CENTENARY OF BENZENE

JUNE 16 is the hundredth anniversary of an epoch-making event, the opening of a new era of civilization. Yet it will pass unnoticed by the multitude that enjoy its benefits. They will go about their business and pleasure as usual; driving motor cars over roads made smooth by coal-tar and level by explosives; they will listen to the music of the phonograph or radio; they will wear gaily colored clothing, enjoy pleasant perfumes and aromatic flavors and ward off disease by drugs and ointments without giving a thought of gratitude to the modest man who a hundred years before discovered the mother substance of these comforts, conveniences and luxuries of modern life, that is, benzene.

For this is one of the silent revolutions of science, originating in a most unspectacular event, plain Michael Faraday, the blacksmith's son, working in the basement laboratory of the Royal Institution in London, separating out from compressed oil gas a few drops of a clear colorless limpid liquid, giving no hint of the potent poisons, brilliant dyes, pungent scents and high explosives that are derived from it.

Benzene is a key compound, we may call it a key-ring compound, for when the chemist draws a diagram of its molecule on the blackboard he makes a ring or hexagon of six carbon atoms, holding hands like half a dozen children playing ring-around-rosy. That is why it gives a chance for so many derivatives. The chemist can attach any kind of atom, or group of atoms, to any of the six carbons and while it makes no difference which of the six he attaches the first side-chain to, it does make a difference where he attaches later side-chains. The chemist has made about 150,000 compounds on the basis of the benzene ring in the century since Faraday discovered it, and he can make as many more if he needs them in his business. All these derivatives are distinct and different, as different as a cat and dog, or as a pot of poison and a pork pie. Most of them are novelties, creations of the chemist, not found in nature. The benzene compounds have added immeasurably to the wealth of the world, to the length of life and to the joy of living.

But the man who first made benzene died poor. He might have made half a million dollars or more if he had turned his talents to commercial work. But he preferred to be a pioneer, and he deliberately set aside the temptations of wealth and title, and devoted his life to the pursuit of pure science. His professional business income during the later and most fruitful years of his life ranged from $500 a year to zero.

Such a man, whose labors contribute to the enrichment of his country and the world at large, instead of to his own profit, should be supported by the nation, but when Faraday was persuaded to apply to the government for a pension, so he could continue his researches in electricity and chemistry, Lord Melbourne, the prime minister, laughed at him and called him a humbug.

But the world knows him better now than did his rulers, and few will be disposed to dispute the judgment of his friend and collaborator, Tyndall, who said that "Michael Faraday was the greatest experimental philosopher that the world has ever seen."

Faraday announced his discovery of benzene to the Royal Society of London on June 16, 1825, and on that date this year delegates of the chemical societies and chemical industries of Great Britain and the United States assembled at the Royal Institution at London to do honor to this great man and to appraise the value of his discovery to the world.

FOOD FROM SHALE

THE oil shales with which our country is so abundantly supplied may some day in the far future come into play to help out our failing food supply as well as our dearth of gasoline. The problem has already passed from the question of possibility to the question of profitability. The chemist is confident that he can make edible fats from shale oil, but he can not yet compete with the cottonseed or the hog.

In fact, the chemist has now up his sleeve processes for making fats from almost any kind of carbonaceous material: coal, lignite, petroleum, wood tar, sawdust and other unappetizing stuff. He can not only make the scores of fats and oils that are found ready made in plants and animals, but he can make hundreds of others that nature never thought of. And those that he has most recently patented prove to be just as nutritious as those that the human race has been living on for the last hundred thousand years or so.

The reason why the chemist can make synthetic fats in such variety is because they are all built on the same simple structure, a long chain of carbon atoms, hand in hand like the chains of paper dolls that we used to cut out of a folded newspaper. Each carbon has two hydrogens attached on the side, except one of the end ones which carries two oxygens. This is what is known as a "fatty acid" and there is a large family of these fatties. All those found in nature have very oddly an even number of carbons in the chain, but the chemist can make the missing odd members that come in between, and so complete the series. The most common fats and oils, such as butter or lard, olive or peanut oil, consist mostly of various mixtures of those members of the family having 14, 16 or 18 carbons in the chain. These are combined with glycerine in the fat foods, but if you substitute sodium for the glycerine, which you can easily do by adding lye—your great grandmother knew how if you don't—you will get a soap.

Now tar, petroleum, shale oil and other mineral oils consist of similar carbon chains, but lacking the oxygen-tipped end which makes the acid. Often indeed the chain has no end, for it is hooked up into a ring. But the chemist has discovered that he can introduce the oxygen by driving hot air through the mineral oil, or by using that concentrated and active form of oxygen as "ozone." The combination may be aided by high pressure and by the presence of some heavy metal, such as manganese, lead or mercury, that acts as a catalyst or carrier for the oxygen. After the oil is cracked up and oxidized by such means, alkali is added and soap is produced. The yield is poor and the process is expensive, but proffer enticing possibilities of future development. In Germany much has been

accomplished in this field, and in the United States many chemists are actively engaged in cracking up petroleum to produce various useful products. What they have found out will not be revealed to the public until it has been whispered into the ear of the Commissioner of Patents, but it is known that they have found it possible to get, not only a greater yield of gasoline, but also fatty acids, and a lot of alcohols and other oxidation products, that are much in demand of late for the new lacquer solvents.

But supposing we can get cheap fatty acids from coal or mineral oils, where can we get the glycerine that is necessary to combine with them to form edible food? To rob the natural fats of their glycerine to add to our synthetic fats would not get us ahead any. One solution to this problem is the discovery that glycerine may be made by fermentation from sugar or molasses. During the war a thousand tons a month were made by this method in England where glycerine was needed in large amount to make nitroglycerine.

But there is another possibility that I will only hint at in closing since it may be regarded as chimerical. These fatty acids will unite not only with glycerine but also with the sugars and starches. This would add to their nutritive power, for such a food would give at once the fats and carbohydrates essential for diet; butter and potatoes, not merely on the same plate, but in the same molecule. How such a synthetic food would taste I don't know, but doubtless the chemist could fix up the flavor to suit.

MOONSHINE MORPHINE

THE offer of a $100,000 reward by Herman A. Metz for the discovery of a process for the cheap manufacture of synthetic morphine calls public attention to the possibility that the chemist may at any moment upset the best laid plans of legislators and financiers, as he has often done before. If the Metz prize, or the still greater pecuniary profits of the process, should instigate such a discovery, the elaborate schemes of tariff regulations and the complicated negotiations for international control would at once become futile.

The opium crop of India might be wiped out as was the indigo crop by the discovery of synthetic indigo in 1902. The British conscience would be relieved of the temptation to maintain an open opium market which caused Great Britain in 1840 to make war on China, and which induced her to block the recent attempts of the League of Nations to suppress the traffic.

If the habit-forming drugs may be made anywhere by anybody who knows how, the question ceases to be an international issue and becomes a matter of local police powers. But then the difficulty would arise of how to prevent illicit manufacture. If the synthetic process were publicly known and simple to carry out, it would be harder to prohibit or to regulate than alcohol, because the drugs are easier to conceal and smuggle and the profits are larger. Morphine and cocaine sell for about $175 a pound, and if they could be made cheaply from chemicals easily procurable, there might arise a thriving industry—or rather business—in moonshine morphine and contraband cocaine.

Although the number of drug addicts in the United States has decreased since the passage of the Anti-Narcotic Act, there are between 100,000 and 150,000 according to the estimates of the U. S. Public Health Service. So there is still a market for the illicit traffic, but we may hope

that the manufacture of such drugs artificially, when we learn how to do it, may be so centralized in a few factories that it may be kept under close supervision. Possibly the patents could be put under the control of the League of Nations or of the Narcotic Committee of the International Police Conference.

The offer of the $100,000 prize indicates that a satisfactory method of making synthetic morphine is yet unknown to the public, though some chemist may come forward any day with the formula.

Heroin, which according to the New York Police reports is used by ninety-four per cent. of the criminal drug addicts, is not a natural product but a synthetic compound, being made by the action of acetic acid on morphine. But morphine has so far been prepared from opium which comes from the juice of poppy pods. The morphine molecule is very complicated and its structure is not certainly known.

Synthetic cocaine is a more practicable proposition and has in fact been actually accomplished. Professor Richard Willstaetter, of Berlin, has worked out three different ways of making alkaloids of the cocaine family, one of which "psicain" is claimed to be a stronger local anesthetic than the natural. Professor Julius von Braun, of Breslau, has been working on the same problem for the last ten years. The synthetic products usually differ from that extracted from the coca leaves. The natural twists a ray of polarized light to left while the artificial is apt to be neutral. Their physiological action may be different also. But on October 31, 1923, a British patent was taken out for the manufacture of left-handed cocaine, identical with the vegetable product.

The primary materials used in making synthetic cocaine are mostly cheap and common chemicals; one of them is citric acid, the lemon acid; another is ammonium chloride, our familiar "sal ammoniac"; and a third is formaldehyde, the household disinfectant.

Several synthetic substitutes for cocaine, such as novocaine or procaine, have come into use, since they are quite as effective and are not habit-forming. Some day, we may be confident, the chemist may find out how to make these useful but seductive drugs, but by that time he may be making other compounds superior to the natural.

ARTIFICIAL FOOD

THE other day Secretary Hoover, in referring to the new German process for making methanol and formaldehyde directly and cheaply from coal and water, suggested the possibility that the chemist may some day be able to make synthetic food.

The first and fundamental question is whether food can be made from earth, air and water. Anybody can answer that question as well as a chemist, for all our food is now made from earth, air and water.

The real questions are: Will man ever be able to manufacture his own food? Must he always be dependent upon the plants for his provender?

These are not so easily answered because food is of various sorts and some are easier to produce than others. As everybody knows now-a-days there are five classes of compounds essential to every well-balanced diet. There are: first, salts; second, fats; third, carbohydrates; fourth, proteins; fifth, vitamins. I put them in this order because this is the order in which the chemist is conquering them.

The first, the mineral matter, is already conquered, for the chemist can make any kind of salts he wants, and he now knows what kinds he wants.

JOHN T. SCOPES

Teacher in the high school at Dayton, Tennessee, who has submitted to a trial to test the constitutionality of the law forbidding the teaching in state-supported institutions of "any theory that denies the story of the divine creation of man as taught in the Bible, and to teach instead that man has descended from a lower order of animals."

"FOR I'M THE LORD HIGH EXECUTIONER

Courtesy of The New York World

The second food constituent, the fats and oils, can also be struck off the list, for the chemist could make any of them out of coal and water if he had to, though he would hate to have to for it is a tedious and expensive process and he would starve before he got enough to butter his bread or dress his salad. He can not only imitate nature in making any of the fats found in plants and animals, but he can make new ones that nature never thought of. I have on my desk a quarter pound of such a synthetic fat, glyceryl margarate, the chemist calls it, that is altogether an artificial compound, yet it is as nutritious as tallow or lard.

The third class, the carbohydrates, comprises a variety of starches and sugars and similar substances. They are very complicated compounds of carbon, hydrogen and oxygen and their structure has only recently been unraveled. The simplest possible compound of these three elements is that containing one atom of carbon, one of oxygen and two of hydrogen. This is formaldehyde, the irritating gas used as a disinfectant under the name of formalin. Now if you multiply the formula of formaldehyde by six you get the simplest of the sugars, glucose. This multiplication of the molecule is easy to do on paper, but if you try to do it in the laboratory you will find it tremendously difficult. Hundreds of chemists have worked

BACK TO THE INQUISITION

Courtesy of The New York World

at the problem and only a few have succeeded and these to only a limited extent. Last summer at the Toronto meeting of the British Association for the Advancement of Science, Professor E. C. C. Baly, of the University of Liverpool, exhibited a bottle of syrup which he had made by exposing a solution of formaldehyde in water to the ultra-violet rays from a quartz mercury lamp for weeks. This had been analyzed by Principal Irvine, of St. Andrew's University, Scotland, and found to contain some ten per cent. of glucose and sugars of similar sort. Principal Irvine at the same meeting announced the synthesis of a starch, which is a still more complicated compound, for starch breaks down into glucose. So it is evident that there is no insuperable barrier to the artificial manufacture of these two forms of food from which we derive most of our muscular energy. But to get even the small amount of sugar that Professor Baly made required enormous expenditure of electrical energy, and it was not fit to eat at that.

To produce the fourth class of food ingredients, the proteins, is much more difficult than the preceding because their structure is more complex and varied, and a variety of them is essential in any diet. One kind of

sugar can replace another and all the fats are likewise interchangeable. We can even get along without sugar if we have fat, and *vice versa*. But we not only have to have some protein in our food but we have to have several particular kinds. A protein molecule may embrace a sugar molecule and will also contain certain compounds containing nitrogen which are called the "amino acids" because they are related to ammonia. There are some eighteen amino acids found in food, but they may not all be essential. Perhaps we could get along on a dozen or less. The constitution of the amino acids is known and they might be made artificially. It has been found on feeding experiments with rats that they will live on a diet without protein if they are fed with the proper kinds of amino acids. That is, they can construct the proteins of their body out of the building blocks of amino acids. So we may not need to go so far as the complete protein to get synthetic food.

The fifth food factor, the vitamins, is still far beyond our reach. We know there are several substances that are essential for any dietary in minute amounts, but we do not yet know how many there are, nor what they are. They are not even named, but are provisionally labeled A, B, C, D, E, and nobody can tell how much farther down the alphabet they will run. None of the five or more has yet been identified. They are all mavericks so far, but we may expect them to be caught and branded before many years. The latest triumph in this field is the discovery that it is possible to form or at least to activate one of the vitamins, in food that does not contain it, by the action of ultra-violet light. This gives promise that the chemist may be able to make them whenever he finds out just what they are.

This then is the situation. Three of the five food factors could theoretically be made in the laboratory, though it may be some time before we make enough of the third to feed a rat. The fourth seems possible and the fifth looks hopeful.

But from test-tube experiment to laboratory production is a long and perhaps unattainable step. Even if we learn how to make the various constituents of our daily diet we shall likely find that in general it will not pay us to do it, for the plants can still make them cheaper than we can.

So to the first question, "Will man ever be able to manufacture his own food?" I would answer "yes." And to the second question, "Must he always be dependent upon the plants for his provender?" I would also answer "yes."